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and

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THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

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Members of all classes are entitled to receive these publications free: for additional copies of the Journal they will be charged at the price of five shillings per part, and of the brochures at the prices stated on the wrappers, varying in proportion to bulk.

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All quotations, technical terms, and localisms should be indicated by means of inverted commas.

Foreign weights, measures, and costs should be given whenever possible; and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case the exact reference to the previous publication should be given.

Communications upon papers read at meetings, notices of personal movements, or other matter for which publication is desired in the next issue of the Journal, should be in the hands of the Editor on or before the last day of January, March, May or November as the case may be. Subsequent delivery may be too late for insertion.

Advertisements in the Journal. A limited number of Advertisements of firms interested in the Petroleum Industry may be inserted in the Journal. Application for terms, etc., should be made to the Secretary.

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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

We have to record with deep regret the passing away, on the 29th April, of our Honorary Solicitor, Sir Frank Crisp, Bart., who has kindly taken in hand all legal matters connected with the Institution since its foundation.

He was born on October 25th, 1843, the only child of Mr. J. Shalders Crisp, and passed through University College School, graduating as LL.B. and B.A. (Lond.). Admitted as Solicitor in 1869, he soon became recognised as specially expert in Company law, and the firm of Ashurst, Morris, Crisp & Co., of which he was senior partner, acts for a very large number of City Companies. He was a Member of the Board of Trade Committee in connection with the Acts amending those relating to Companies. A Baronetcy was conferred upon him in 1913, in respect of his valuable services.

Besides his high legal attainments, he was a distinguished horticulturist and microscopist, acting as Honorary Secretary of the Royal Microscopical Society from 1878 to 1889, and as Vice-President and Treasurer of the Linnean Society from 1881 to 1905. His gardens at Friar Park, Henley-on-Thames, are among the finest in the country, and their electrically-lighted caverns contain many interesting objects.

Though well into his 76th year, he was constant in attendance to his professional work, and was at his office in Throgmorton Avenue but a few days before his decease.

At the funeral, which took place at Henley, the Institution was represented by the Hon. Sec., Mr. A. W. Eastlake.

We much regret to learn that Dr. A. U. M. Schlaepfer, a Student of the Institution, died on April 6th.

Mr. J. W. Burford has been appointed Manager of the Lobitos Oilfields.

Mr. T. R. H. Garrett has left for Assam.

Mr. Charles Greenway has received the title of Baronet in recognition of his valuable services to the State in connection with the Petroleum Industry.

Mr. G. W. Halse has returned from Mesopotamia.

Mr. E. Lawson Lomax has returned from the United States of America.

Mr. C. B. Rosenplaenter has left for Algeria.

[The usual editorial article is suspended for this number on account of the plethora of matter calling for insertion.]

The Application of Electrical Power to Oilfield Requirements.

Mr. J. W. Burford replies to the remarks on his paper as follows (see vol. iv, pp. 262–276) :—

In reply to the discussion on my paper, delayed by pressure of business, I think the best thing to do will be to deal in turn with each gentleman who took part in the discussion ; but before doing this I would like to express my thanks to Mr. Holiday for having been good enough to read my paper before the members of the Institution. I would also like to thank the Chairman for his kind remarks.

Mr. Herbert Barringer: It is very satisfactory to know that such an eminent engineer as Mr. Barringer agrees as to the suitability of electrical power for oilfield work. As regards the source of the electric power, I feel sure that Mr. Barringer would advocate the installation of a generating plant, if final results showed a substantial saving in £. s. d. over the direct employment of steam plant.

Mr. C. Dalley: I am much interested in Mr. Dalley's remarks, with which I am in almost complete agreement. As regards the comparison of Diesel engine and steam-turbine plant, I think the question depends upon the size of the plant, and the matter of suitable boiler-feed and condensing water. A Diesel engine, if worked well within the limits of its capacity, will be an excellent servant, and I have had personal experience of one small engine which worked daily for twelve hours per day, for two years, at about 60 % load, without once having the piston taken out or the main bearings touched, while some large engines proved to be a very painful experience, due to working with heavy overloads and with unsuitable fuel oil. I do not think there is much doubt that Diesel engine units, suitably loaded, and in sizes up to about 250 K.W. capacity, would prove much more efficient than turbine units of similar size. I do not think that liquid controllers are suitable for drilling equipments.

The thermal efficiencies for Diesel engines are approximately, Indicated H.P. 45 % : Effective H.P. 34 %.

Mr. R. J. Ward remarks that the speed of bailing in Baku,

with every kind of motor, was more or less constant, and that the speed of 1,800 ft. per minute of the electric motors drew much sand into the well. Electric motors can be procured with a very wide range of speed, and practically any regulation required. Complete breakdowns in well-regulated power-houses should be unknown, except under very exceptional circumstances.

The charge of 1¾d. a unit for power appears to be high, and 1 K.W. hour should be produced for ¾d. or 1d. on most oilfields with a self-owned generating plant.

Mr. J. C. Templeton: My reference to Mr. Rappoport's paper was merely to show that the electric motor could not be considered a "rank outsider," but that its application was steadily progressing.

As regards details of faultily-designed installations asked for by Mr. Templeton, I would, first of all, refer to the many instances where motors far too small for the work required of them have been put in; secondly, to the installation of constant-speed motors for variable-speed work; thirdly, to the adoption of ordinary plain switchgear, with no overload or no load release; fourthly, to the absence of interlocking arrangements of switchgear to prevent damage to motor by careless switching; fifthly, to the use of metal fuses.

Referring to Mr. Templeton's comparison of cost of steam and electrical drilling plant, my figures are £6,486 and £2,740 respectively, not £6,488 and £2,510 as noted.

As regards the comparison between the different kinds of plant in the next paragraph, I do not quite perceive how Mr. Templeton arrives at the figures of 827 H.P. and 482 H.P. as my figure for steam estimated horse-power, for the same requirements, is 800 H.P. This difference cannot be called one of thermal efficiency, but is due to the difference in rating given by manufacturers of gas motors, and of electrical motors. As already mentioned in the paper, gas-engine manufacturers rate their engines by giving the maximum H.P., stating that the engine must not be worked at more than 80 % of this figure, for a twelve-hours' run per day. Experience proves that, should the engine have to run for 24 hours per day for 365 days per year, with sea-water for cooling the jackets, and with indifferent attendance, 50 % of the maximum B.H.P. should not be exceeded for satisfactory service. Makers of electrical motors specify the B.H.P. on continuous rating, with usually a momentary overload capacity of 75 %, and 25 % for one hour. Hence it comes about that a 15 B.H.P. motor is capable of doing the work of a 30 maximum B.H.P. gas engine.

Answering Mr. Templeton's last question, steam was taken for

comparison, as the case was an actual one. The internal-combustion engine drive at the well would require the addition of a reverse clutch, or probably twenty reverse clutches costing over £100 each, as the author's experience of reversing clutches for drilling service is that they are absolutely unsatisfactory, causing innumerable shut-downs and delays and costly repairs. One of the best-known makers of reversing clutches for drilling engines was asked by the author's Company to supply a clutch that would stand up reliably to its work, and the makers offered to make their heaviest type of clutch, entirely of cast steel! Electrical pumping and drilling outfits can quite safely be left to look after themselves for many hours at a time.

Mr. C. McCarthy-Jones' remarks call for no reply.

Mr. M. A. Ockenden: I agree with this gentleman that a careful record should be kept of boring operations, where electricity is being used, as a guide for further applications.

Mr. Arthur Millar: I quite agree with Mr. Millar that the swabbing methods used in Galicia open up possibilities for the application of regenerative control. I am pleased that Mr. Millar referred to what he terms the slogan of the anti-electrical party, regarding the source of power being in one building. Properly-designed and supervised power-houses are to-day more reliable than the steam-plants found at independent drilling rigs.

The Geology of the Persian Oilfields.

[Mr. B. F. N. Macrorie contributes the following to the discussion of the paper of Messrs. Busk and Mayo, pp. 8–33 of this volume.]

The authors of this paper say that it is the result of the joint researches of the above (the regular Geological Staff of the Anglo-Persian Oil Co., Ltd.), "together with those of Mr. B. F. N. Macrorie." This may be understood as a suggestion that I am in accord with all the opinions and conclusions expressed in the paper. From early in 1915 until the beginning of 1918 I was the titular head of the Geological Staff of the Anglo-Persian Oil Co., Ltd., and, as such, was not only responsible for directing, arranging and allocating the field work, but, also felt that, whenever the Home Geological Advisers could not accept the remarkable and startling field evidence brought forward by Mr. Busk's most painstaking work, it was my duty to act as umpire on the matters in dispute by seeing the evidence on the ground. Wherever it was possible to do it in addition to my other duties, I went over with Messrs. Busk and Mayo some of the ground about which scepticism had been

expressed as to the evidence by the Home Advisers, and in the main was able to agree and confirm their observations, but I could not accept, as proved by the evidence, such conclusions as that the main Maidan-i-Naftun thrust fault could have such a great displacement as 12,000 feet, or that the main oil zone of that field is disturbed by minor faulting of its own, different in type and discordant in strike from the minor folding evidenced on the surface.

It is admitted that the detrital limestones often are the oil-reservoir rocks, but there is much evidence that the Persian oil is not confined to them. The writer has spent much time on the detailed study of the Maidan-i-Naftun well logs, and there are several instances where it is recorded that oil was struck in gypsum and rock salt. At Marmatain several outcropping beds of nearly pure gypsum are blackened, and smell of petroleum when freshly broken. A sample was brought to England and analysed by Dr. A. E. Dunstan, who found 0·56 % of inspissated petroleum in the specimen. In the Kohat District of the North-West Province of India, the writer visited a salt quarry where the rock salt was blackened for a thickness of several feet, and, similarly to the Marmatain gypsum, had a strong petroleum odour and stain to the fingers on fresh fracture. In Persia, the gypsum beds, as well as the detrital limestones, can be traced and found to vary laterally, the gypsum altering from a white crystalline form to a brown, impure, sandy and cavernous form. It would thus seem possible that the oil in the gypseous beds (which, as Mr. Busk says, becomes quasi liquid under pressure) would, when that pressure was applied, be squeezed out of the crystalline gypsum to migrate to the nearest sealed porous reservoir, which may be cavernous detrital limestone or sandy gypsum. Therefore, it does not appear proved that the detrital limestones must needs be the only important reservoir rocks.

With regard to Mr. Cunningham Craig's remarks the writer recalls that, as a matter of written history, in Mr. Craig's Report of his visit to Persia in 1907, he says he only observed one fault, which was of no material importance to the prospects of an oil-field, and this fault is shown on his map as being one of the smaller faults, since definitely proved on the north-east part of the field. The writer was credibly informed that a great dislocation to the north of Marmatain was pointed out to Mr. Craig, who, instead of recognizing it as a big thrust-fault, interpreted the section as proving his theory that the gypsum beds did not occupy a constant position in the Tertiary system, because in this section they overlaid Fars sandstones, whereas at Marmatain, 10 miles southwards, they were overlaid by the same sandstones. B. F. N. M.

Thirty-Sixth General Meeting.

This Meeting was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday, 18th February, 1919, Dr. Ormandy occupying the Chair.

The Members of Council present were Mr. Andrew Campbell, Dr. A. E. Dunstan and Mr. Arthur W. Eastlake. Messages of regret for unavoidable absence were received from the President, Prof. Sir John Cadman, Dr. F. Mollwo Perkin and Sir Boverton Redwood, Bart., the latter and the President on account of illness.

The Chairman, in opening the meeting, announced that the President, Mr. Charles Greenway, was unfortunately at home ill, not having been able to go to business for the past week, and had telegraphed that he much regretted that the doctor forbade his attendance at the meeting. Sir Boverton Redwood, the senior Vice-President, who would have taken the Chair in the absence of the President, had also unfortunately fallen a victim to the prevailing illness, and had telephoned saying it was quite impossible for him to leave the house for several days. In the absence of those two gentlemen he would do the best he could to fill a place for which they were much more capable than himself.

It afforded him much pleasure to call upon Mr. Montagu Summers to read his paper on "The Financing of Oilfields." To any ordinary intelligent audience the question of finance appealed as being of the very greatest importance. People might possess all the technical skill and knowledge in the world, but unless they had the sinews of war to enable that knowledge to be made use of, it was a hopeless sort of commodity.

The following paper was then read :—

The Financing of Oilfields.

By Montagu Summers.

The reading of a paper entitled as the present one, "The Financing of Oilfields," limits one to a fairly circumscribed area of subject. Unlike what is usually given at these gatherings, the matter for construction must necessarily be of a somewhat dry nature. This, however, should not make it lack interest to the receptive mind for facts which form the fundamental basis for the fostering of so great and extensive an enterprise as the Oil Industry.

To-day it must be admitted, without hesitation, that petroleum deposits are an essential form of national asset, the value of which is almost inestimable. The competent handling of petroleum

deposits is of the highest importance to any nation. Usages to which oil is now put, revolutionising ideas of motive power and holding out for the future things that may be said to beggar conception, make the subject of financing of present and prospective oil resources on a comprehensive basis an all-absorbing one to those who hold the welfare of Empire at heart.

That being the case, while I am handicapped in the reading of this paper, inasmuch as it does not admit of dealing with highly technical illustrations and discussions, nor allow of the interlude of screen-views of foreign countries, or interesting notes on travel so dear to the heart of a lecturer, I hope to give figures that may prove of sufficiently startling and instructive a character to retain your interest in what I consider of paramount importance to all who view, as I suppose we here do, the inexhaustible future for oil.

Finance should be held in esteem by us all in a larger or smaller degree, and, in endeavouring to lay before you facts showing what has already been done in promoting the ramifications of oil enterprise, I will try to lighten the details of so concrete a subject as much as possible.

Commerce and Finance.

Most of us are pleased to hear that there is about to be formed a Ministry of Commerce. This country having always been first and foremost a commercial one, forgiveness might readily be granted for an expression of surprise that such a Department was not established many years ago. Being well aware that commerce may be, and has been, properly described as 'the sinews of the Country,' I would like to submit for your approval that finance is at the same time 'the nerve of the Empire.' Following on this conclusion of the vital nature of finance as regards Empire, it is surprising that no attempt has at any time been made in the past to place the work of the financier in the category of a professional occupation. Nevertheless, few will deny that the making of a financier entails years of training to give the proper and exact knowledge required for the carrying out of the gigantic schemes that are now launched for the advancement of public and national enterprises. Even so, while many are called, few are accepted as arriving at the position of real experts.

The successful financier needs in many instances to be a cosmopolite. I would express the opinion that beyond the mere matter of many years of financial experience at home, no man can hope to become a sound financial expert who has not had the advantage of a considerable acquaintance with foreign countries and our own

colonies through travel and business. It would probably not be an exaggeration to look upon the financier as born and not made. There is a kind of intuitive foresight of generally unseen possibilities in things that places the financial expert apart from his fellows. In dealing with such a complex problem as afforded by the eccentric and uncertain conditions, in many instances, surrounding the resources of petroleum deposits, the instinct for provision against the vagaries of all drilling and mining operations is required. Big results can never be expected without large and courageous efforts, so that the real financier is above tinkering with the development of a new enterprise with insufficient capital. His aim in any venture is to provide against abortive enterprise that, by discouraging in any way the work of development, might put back the clock for an indefinite period in connection with that enterprise as a whole.

Position of the Promoter.

A word for the promoter seems to me to be necessary owing to a good deal of misconception of the personal qualities of such a person; the term "promoter" has been undoubtedly applied in an invidious way to many quite honourable men in the City of London. It is as well, however, to bear in mind that there are promoters and promoters. There are men of strong character engaged in the business of promotion, but those found with weakness are unfortunately the type usually presented to the public eye. Despite this fact there are many highly respectable promoters, but at the same time I do not wish to avoid admitting that some are, perhaps, shall we say, barely on the borders of respectability. There is what has been described as the "guttersnipe" promoter, and what was known as the "Bodega underwriter," but the War has well served the City and the public at large in finishing off this class of gentleman, I hope and believe for all time.

Be this as it may, I do not think that even the discredited class of promoters is much to blame for the many failures that have taken place during the past decade in Oil Companies. The greater cause of mischief has been more often due to the custom adhered to, or system generally adopted, in this country for the launching of enterprise. If the genuine promoter's career were carefully studied, I have little doubt that the large risks taken by him would surprise many of you. From my own experience he far more seldom than might be supposed wins a prize. To get a sound idea of what promotion means, it may be stated that our own Government is one of the biggest promoters in the universe, and our leading bankers are also promoters. Someone, or some persons,

whether singly or as a corporate body, must be behind any issue as the founder or promoter. This is the case whether it refers to a foreign government loan, a large industrial scheme, a gold mine or an oil proposition.

The System of Company Promotion.

That the system of promoting Companies in this country leaves much to be desired, and that it is open to all sorts of criticism, may be readily conceded, but it must not be forgotten at the same time that there are no industrial banks or other institutions in England similar to those in the United States and on the Continent. Lacking these facilities for financing a speculative enterprise in its early stages, whatever its claim for prospects may be, we have only the promoter to fall back upon, and it cannot be expected that he will undertake the financing of a concern unless he puts a profit on the undertaking commensurate to the risk that the future of the enterprise appears to present. Margin must be allowed which will refund him his initial expenses, and give him a profit for himself. It is, therefore, a foregone conclusion that for these items the public have to pay eventually.

An actual cash profit, however, is frequently not forthcoming to the promoter. In a great number of instances his profit is principally taken in shares of the Company. More often than not he may have to wait years effectively to obtain the profit, which is barely an adequate return upon his original venture. There must be a certain amount of admiration shown for the pluck displayed by many men in these kinds of transactions, be the merits or demerits of the body of them what they may. When risks are large, the prize possible to be gained must of necessity be of attractive proportion.

Further, it is not generally realised how sensitive finance is. With all the care in the world, through some political event or trouble in a foreign country, a black cloud, although perhaps only temporary, may cross the financial horizon. It may have no real connection with the particular enterprise whatever, and yet be quite sufficient to wreck the little ship that the promoter has carefully built. I may give one instance of this.

At the time when enormous interest was taken in Western Australian mining, a promoter spent about £10,000 in acquiring options over 48 out of a total of 50 tin properties at Greenbushes, Western Australia, in the Jarrah country, including the smelting works Company, in one of the healthiest parts of the Colony, having splendid railway facilities, at the door of the mines. He was about

to form a combination of the whole through a new English Company. The enterprise was a perfectly sound one, and the profits were reckoned on the basis of tin at £65 per ton (you know the price of tin to-day). Everything had been carefully arranged, the prospectus printed with a first-class board of directors, and he had just started on underwriting the issue when what is known as the "Bottomley Smash" occurred. I need hardly mention to anyone with knowledge of City affairs, that it became impossible to do anything with an enterprise in Western Australia then, however good its prospects, therefore the options expired, and the promoter lost his money.

Many people do not realise that in Companies interested in certain commodities there are fashionable periods, and I should say without hesitation that the most fashionable to-day are Oil Companies.

I do not think that anyone can deny the fact, that had it not been for the venturesome enterprise of Englishmen in the past in connection with concerns that have often appeared of problematical value, this country would have been the poorer by many millions of pounds sterling. Undertakings which at times have given the idea of the wildest of wild-cat schemes have eventually been the means of providing a large proportion of the raw products of the world that are required by our manufacturers; this is particularly of almost paramount importance at the present moment. Loss of commodities through the decline of spirit for venture would be a disastrous thing to contemplate.

The English Joint Stock Acts for corporative Companies have been brought up to date so far as 1917, and since then a Commission has been formed to revise them further.

The problem is a difficult one, and we must hope that the opinions of only men with wide experience on the subject will be taken with regard to any proposed alterations, as otherwise untold injury may be done to all kinds of enterprises in this country, and lead to endless complications.

We all know that no set of laws or Acts of Parliament can be perfect, or can be so constructed that they will not bear harshly under certain given circumstances, but speaking from personal experience of the French Companies Acts (which, as you know, is under the Code Napoleon, and besides France apply to most of the countries in the Near East), and of the Acts regulating Public Companies in America, I am of opinion that the English Companies Acts, as they exist to-day, are superior, more just and less liable to be used improperly, and give a greater protection to the investing for which they have been chiefly framed. We must also neve

forget the great service that the Joint Stock Companies Acts have rendered this country in the way of new ventures, such as railways, shipping and innumerable enterprises, whereby the risk has been distributed to the many instead of the few: they have helped to make our Empire what it is.

Speculative Nature of Oil Finding.

There is nothing gained in trying to hide that oil finding in its early stages must always be a speculative business. The possibilities of very big things are quite good, but there must also be blanks to draw (as in gold and other mining for metals). Comparing the initial expenses of boring for petroleum with those in connection with mining for gold or copper, they are far less in the former than the latter case.

I have already given you instances of struggle and failure of oil production, but as representing the big prize series, there is the case of the Mexican Eagle Oil Co.'s No. 4 Well which has had an output of 100,000,000 barrels of petroleum. An idea of the Mexican Eagle Co.'s enormous business can be gathered from the fact that in addition to the local sales in Mexico, over 15,000,000 barrels of oil were shipped during the last financial year from the two ports Tuxpam and Tampico.

It might be as well to bring to your notice what should be remembered as a striking instance of the 1910 boom. I refer to the Kern River Oil Fields of California. In 1912 a drastic writing-down of capital had to be submitted to, but ever since the reorganisation the Company (with its subsidiary, the St. Helen's Petroleum Co.) has made steady progress.

Lack of Expert Advice.

A great boon to the Oil Industry in the country to-day is the establishment of proper schools of training for oil experts. The lack of expert advice was one of the greatest things we suffered from in this country in the early stages of the petroleum industry (I mean boring for oil, not working oil shales). The difficulty of obtaining really reliable expert advice on oil production has in the past been singularly noticeable in comparison with every other class of work.

There were plenty of capable and reliable men well versed in mining for all base and precious metals, coal, etc., but it has been possible to count on the fingers of one hand all the really prominent and sound men available in this country, belonging to the oil world, capable of giving a reliable report on oil lands. It is a

regrettable fact to have to make this admission, but such has been found to have been our unfortunate position.

We can only trust and hope that now proper schools for training oil experts have been founded in this country, we shall be in the near future in a position to secure all the services we require of reliable experts who have specialised in petroleum production, in the same way that we can obtain experts in every other class of industry. There is not to be forgotten in this connection the great assistance and impetus given to this subject of national welfare by a body of research like the Institution of Petroleum Technologists (to the founders of which the British public certainly owe a debt of gratitude).

Estimated Capital in Oil.

Public interest in the Petroleum Industry (except in the mining for oil shale) can only be described as quite young so far as this country is concerned. Concentrated attention on the oil business may be put at hardly more than 15 years. There were, of course, a few pioneers of somewhat earlier date, but the contrast of the oil industry then and now is distinctly striking, especially from the point of view of the capital employed in the exploitation of the various oilfields.

The amount of capital invested in oil enterprise during the period mentioned above is very large, and probably of greater proportions than in any other industry outside the maintenance of railways. I estimate that the amount of authorised capital in limited liability Companies to have been about £190,000,000 sterling, and of this there has been issued some £125,000,000. It is difficult to come by exact data, but I think that of the latter sum (£125,000,000) about £20,000,000 is what might be described as "watered capital." I should therefore put the loss to the British public, owing to indifferent and improper finance, bad management of properties and other causes, at £15,000,000 in round figures.

This figure of £15,000,000 may appear somewhat large as representing a loss to the public, but I am assured it is not nearly so large an amount as that lost by the public in the exploiting of several other minerals. While the statement of this big figure of loss may seem to stand out as an ugly feature of oil finance during the past 15 years or so, it must always be borne in mind that the general public have come by far more than this amount through the successful ventures that have been run with adequate financial facilities, and have been properly managed under expert advice. Proof is not wanting in respect to this question, as it is sub-

stantiated by the present market value of the existing Companies, amounting to approximately £250,000,000.

Looking aside from the large sum of money (£125,000,000) invested by the public in this country in Companies under the supervision of English Acts, I find that the amount of capital invested in Companies registered in America and principally subscribed by Americans is over £380,000,000. Taking this big sum into consideration we arrive at the stupendous figure of £505,000,000 sterling invested in petroleum Companies. No account is taken, in arriving at this position, of the many other industries allied to this greatly important one of oil production, while ignoring all those industries that could not continue existence without support from it.

Capital in Mexican Oilfields.

The important character of British interests in the oilfields of Mexico alone is illustrated when we find that the British and American capital invested in Mexican oilfields is over £61,666,667 sterling, of which £20,555,558 is English. These figures must surely impress upon us the extensive importance of the oil industry to the British Nation. Going back to 1901, the oil production of Mexico was only 10,345 barrels, but for 1917 there were given 55,292,770 barrels.

The World's Production of Oil.

According to the estimate given by the United States Geological Survey, the total world production of crude oil up to 1917 is figured at 6,983,567,246 barrels of 42 gallons.

Going back well over half a century, the world's production for 1860 was only 500,000 barrels, but by 1916 it had risen to 460,600,000 barrels, and in 1917 had advanced to the extraordinary figure of 503,708,000 barrels.

Empire Oil Resources and Control.

The great and paramount importance for a proper control of all the resources for oil production in the hands of the British Empire must without hesitation become a very prominent and urgent question, the consideration of which cannot for long brook delay. Petroleum, with its endless new developments, or perhaps I might say the endless new uses for petroleum products, must force a recognition for careful organisation to deal with Empire interests, bringing to the industry the most able management and expert advice obtainable.

I have reason to believe that our Government is fully alive to the urgency and importance of the matter, and that action is already being taken towards the desirable end of placing the oil industry on a national basis. With the suggestion by Lord Curzon that the war was won on petroleum, there arises the great and possible prophecy that the industrial future of the Empire may depend upon the careful management and conservation of oil products.

What must give stress to this need for an all-British organisation of a thoroughly comprehensive and representative character, effectively controlling the present and prospective oil resources of the Empire, is the coming failure of American oil supplies. Some American experts go even so far as to say that, at the present rate of consumption, the supply of crude oil in the United States will cease soon after 1930. This of course is no doubt the worst view of the conditions, but it at least emphasises the importance of careful control and management of new oilfields. Adding to this serious question of future supplies, we must all be aware, is the large amount of oil and oil properties destroyed in consequence of the war in Russia, Rumania and Galicia. If the American estimate is only partially correct, the position of future supplies of oil gives rise to serious consideration.

The recent records of the Anglo-Persian Oil Co.'s business are instructive of the great value of the oil industry, viewed in the light of a national asset. Mr. Charles Greenway (your President), in giving as full an answer as possible to the question as to what extent the Company had been able to assist the Navy by deliveries of oil fuel, has explained that the Admiralty and the War Office having their substantial supply to draw from in addition to others had rendered great service to the operations of the Allies.

By the competition which this source of supply created the nation was undoubtedly saved millions of public money, in the lower prices at which the Government was able to purchase the balance of its supplies. It would not be wise either politically or economically for the Government to rely upon any one country as its sole source of supply of oil fuel, says Mr. Greenway, though the Anglo-Persian, with the extensions it had under contemplation, would doubtless in time be able to provide the whole of the British Naval requirements, and also the requirements of the Government generally for all petroleum products.

We must agree with Mr. Greenway's submission that the Minister or Cabinet who first recognised the essential fact of securing control of the Anglo-Persian Oil Co., and who thereby established an important source of supply, free from

foreign or monopolistic domination of any kind, of a commodity which is necessary for our national existence, performed a greater service to the country, both financially and politically, than even Disraeli when he concluded his historic purchase of Suez Canal shares.

What is wanted, according to Mr. Greenway's view, is an extension of the policy initiated when the Government secured the controlling interest in the Anglo-Persian Oil Co. The formation of an all-British Company similarly controlled is desired to deal with the development of oilfields outside of the British Isles. A likely failure of the United States to be able to maintain the export trade of oil fuel for many years longer makes it urgent that something should be done.

What the Future Presents.

Since the inception of the oil industry the United States has been, and probably will continue to be, the dominant factor in the supply of petroleum for the world for some years to come. We find that for 1917 almost 67 % of all oil produced had its source from there, being 335,315,000 barrels. Russia produced 69,000,000 barrels, and Mexico as previously shown 55,292,770 barrels.

As a further and more concrete example of what the United States has contributed in oil production, it is worth drawing attention to the figures of the world's production from 1857, when the oil-producing industry is generally supposed to have commenced. The figures are approximately 7,000,000,000 barrels of oil, and of this immense total produced from 1857 to 1917 the United States was responsible for 4,252,000,000 barrels, or 60 % of the total.

The tremendous importance of the United States in the oil industry of the world is, therefore, clearly indicated, and what this fact meant in time of war so it must continue to mean in peace, and probably more so. Several emphatic statements have been made by responsible men as to the value of oil for services in war. Mr. Walter Long has said "that oil is probably more important than anything else. You may have men, munitions and money, but if you have not got oil all other advantages will be of comparatively little value." Experience has shown there is no gainsaying such a pronouncement. Everything we have passed through has substantiated it.

Turning to the new peace era in the oil industry, the dawn of which is with us, we have, therefore, still to look to the United States as the backbone of the world's oil production. For this reason—and, perhaps, for this reason alone—the absolute necessity

for the fostering and extension of British interest, with all the energy, all the resource and all the enterprise we are able as a nation to put into it, is fully demonstrated. Conservation of American oil resources is being urged by prominent men to enable that country to meet the demands of the future. Expectations are that the continued improvement of the motor-engine, and its extended application to nearly everything for which power is required, will make the uses for petroleum in its various forms increasingly greater than it has been during the period of the war.

The necessity of reconstructing the neglected as well as the devastated areas will bring into use the most modern up-to-date classes of machinery, and the re-establishment on an adequate basis of the world's Merchant Marine, a large portion of which will undoubtedly be reconstructed so as to use oil, must make the anticipation a reasonable one.

I have no hesitation in endorsing the statement that as a whole the future outlook for petroleum holds nothing but promise of prosperity to those engaged in its production. While not advocating over-temerity, it behoves this country to support unflinchingly the great endeavours that are being made in numerous directions to extend British influence in the oil industry. The hastening of the time when British supplies of petroleum can be independently guaranteed is a necessity, in all probability, to the security of national existence.

In making this great effort a certain percentage of loss must be looked forward to, but, as a nation jealous of our history of pioneering and venture, if the aggregate of financial support makes for success of the British Oil Industry leading towards Empire supremacy in petroleum production, then we shall have achieved in this direction as full a measure of satisfaction as has been obtained in almost any other class of industry.

That the shares in the established concerns for oil production have held, and are still holding, the attention of investors, and that the new undertakings coming forward for the exploitation of lands presenting opportunities for oil producing, continue to attract an increasing proportion of speculative interest, goes to no little extent to establish an assurance that the possibilities for good results have so far outweighed any disappointments and failures that have had to be faced by subscribers up to the present.

DISCUSSION.

The Chairman, in opening the discussion, said that in the early part of the paper the author deplored the fact that he was unable to have those adventitious aids which authors in general were able to make use of in the way of lantern slides in order to make the subject interesting. He ventured to submit that in spite of that statement the author had succeeded, without such extraneous help, in putting the subject forward in such a way that it was bound to be of interest to all. He was sure the members deeply regretted the fact that the President was not able to be present, because he could have taken an active part from first-hand information in the discussion on a subject of such a nature. Many others who might be designated as the smaller fry could only deal with the question from a somewhat academic standpoint, and that was all he personally could do. Sir Boverton Redwood had sent the following communication, which he was sure would prove of much interest to the members:—

Sir Boverton Redwood wrote:—

I have no expert knowledge of finance, and it would be out of place for me to offer any remarks on the methods by which the enormous capital invested in the petroleum industry has been obtained.

The lecturer has told us that finance should be held in esteem by all of us, and with that dictum I am fully in accord, for it is obvious that without finance there would be no scope for the services of that profession in which we, as petroleum technologists, are engaged. It is also obvious that inefficient financing may operate prejudicially to the interests of the petroleum technologist, by involving him in disastrous consequences for which he is not responsible.

It follows that the subject of this thoughtful paper is one of interest and importance to the members of the Institution.

There is, however, one part of Mr. Montagu Summers's paper on which I should like to comment, and that is his reference to the need which has existed in the past for competent British expert advice in oil matters.

Some of you may remember that I referred to this need in the remarks which I made in explaining the aims and objects of this Institution on the occasion of the Inaugural Meeting five years ago.

I then drew attention to the increasing difficulty in procuring the services of properly-trained geologists, engineers and chemists, with the result that positions of responsibility are given either to

incompetent Britishers, or to proficient men of other nationalities.

I further said that, in the absence of any means of gauging the capacity of those who proffer advice, whether in the form of technical reports, or otherwise, capitalists are often induced to give credence to untrustworthy statements, and are thus led astray, money being wasted, and discouragement created.

It is gratifying to find that the lecturer appreciates the value of the services which this Institution has already rendered towards meeting the deficiencies to which I have alluded, and his remarks will be an encouragement to us to further activity.

Mr. W. Brown desired to endorse the remarks the lecturer had made in regard to the wisdom of a Government in the past, an Asquithian Government, that was able to accomplish the deal with the promoters of the Anglo-Persian Company which led to such brilliant results. He suggested that under similar conditions it was within the province of a Government that fully used its opportunities and performed its obligations, to come to the aid of such an industry as the oil industry, which was of vital importance to the conduct of national affairs. In the case of the Anglo-Persian Company the deal was carried out on the highest possible level of morality. The deal was morally sound and, as every moral bargain must be, it was financially advantageous to both parties concerned—not only to the Company, but also to the Country.

He suggested that the bargain with the Anglo-Persian Company should form a model on which the State should work in connection with other oilfields; that was not the only oilfield in the world by any means which could be developed in the same way. When an Institution like the Institution of Petroleum Technologists could lay before the Ministry of Commerce, which was to be formed, a report, backed by two or three of its members whose names were held high in the profession, recommending the Government to become partners with the promoters or the owners of the property in exploiting a particular area, it should be more or less an instruction to the Ministry of Commerce to proceed to make terms with the owners or the promoters of the undertaking. No doubt in the course of time losses would be incurred on some undertakings, and then the Public and the Press would probably be up in arms at once, saying that the British Government was robbing them of their hard-earned savings by acting as oil prospectors; but he was inclined to think that the wisdom of the democracy would prevail, because they would see it was an absolute necessity that periodical losses should occur in connection with such undertakings.

He was exceedingly glad that the first venture had been such a success. If the Anglo-Persian Oil Company had met with failure instead of success, he was inclined to think that the British Government would not have gone into the oil business again for many decades, but the success had been such that he hoped it would not be long before they repeated the experiment in another part of the world. The British Empire was big enough and rich enough in the important product of oil to make the Empire very nearly, if not entirely, self-supporting provided only that it would use the sources of supply which were available. The country was now much wider awake than it was ten years ago in appreciating the sources of oil which existed within the Empire.

It was to be hoped that at last a perfect Government existed which saw that it not only had to give increased wages to the miner and the munitioneer, but also to come to the help of the capitalist when he required that help. The industry was such that every now and then a large amount of money was made by the fortunate and hazardous prospector. It was an industry in which those who ventured must be prepared to lose not only once but twice or three times, and, there being such a risk, it was an enterprise which commended itself to the British public, which loved a gamble. But it was also an industry that must commend itself to the Government, because of the needs of the nation; and he further suggested it was an industry which should commend itself to the scientist, in view of the many interesting scientific problems that were connected with it. All said and done, it was an industry that it would pay the country to foster, and he hoped the Ministry of Commerce would not neglect the opportunities that would be placed in its way in that connection in the future.

Mr. A. MacDougall, after adding his tribute of praise to the lecturer for his excellent paper, said he desired to endorse the view, which he thought was held by everyone present, that the Government of the country should hold a predominating interest in the production and distribution of oil throughout the Empire. As one who had been connected with the industry for about 25 years, he knew that an immense amount of capital was necessary for such undertakings, and it was most important and absolutely essential that that capital should be properly and wisely directed. The lecturer was evidently of the same opinion, because he had suggested that oil experts should be trained, and in that connection had mentioned the educational facilities that were provided by their own Institution. Personally, he was one of those whom the Government had now taken under its wing, and he thought they had

adopted a very wise line when doing so, i.e. they had continued as far as possible to utilise the services of those who in the past had been in what might be called "the oil swim." It was a very limited pond at one time, and all those connected with the industry knew each other by name; but he thought the policy the Government had adopted was a wise one, because it ensured the services of those men, who through years of experience, were skilled in the industry.

Mr. David Fell said he did not know that he was competent to speak on petroleum oil or even on shale oil, although he had had some considerable experience in connection with the financial aspect of the shale industry and with Company-promoting. He was glad that the lecturer had not spared those promoters who went in for "wild-cat" schemes. Personally, he desired to speak from the point of view of a man who was not in the environment of the City, but who belonged to the oversea Dominions so often condemned by investors here for having produced bad investments.

With regard to the question of the Government taking an interest in the oil industry, he could not imagine any Government putting money into any Company, oil or otherwise, in which the promoters or those who held the original shares were allowed to sell their shares before the Company was a paying concern or self-supporting. If they did that they would be lending public funds to a body of gentlemen who might possibly push the concern by means of a system of advertising and high-coloured reports. Whatever assistance was given the Government must be careful to see that the money was being used in connection with a *bona fide* investment.

With regard to the question of promoters' shares, he held that many Company promoters in London were secured by some gentleman of mediocre capacity from overseas, who had some particular project which he regarded as suitable for Company-promoting in this country, whereas nobody in that region would look at it. Perhaps they might not have the speculative or adventurous instinct; at any rate, he had not sufficient influence to inspire enough confidence to induce people to take it up over there, and as a consequence he made for this country, often with successful and highly-remunerative results.

The fact must also be kept in mind that men were sent out overseas to conduct affairs who had no idea of the political or industrial environment there existing, although they were no doubt highly competent technical gentlemen. For instance, a first-class geologist might write a report in connection with an oil-shale bed who knew nothing whatever about the distillation of oil, and

thousands of pounds had been subscribed in this country on such reports, because people assumed that, because a geologist was competent to give an opinion upon a shale bed, he was also competent to give an opinion on the retorts used in the distillation of oil. He thought a great part of the trouble that had occurred was very often due to the fact that very highly respected expert gentlemen were put in charge of particular branches of the requirements in which they were absolutely ignorant. So far as he was aware, there were comparatively few people in this country who knew anything about the distillation of shale-oil. He thought much could be done in that respect, because in this country there was an abundance of shale beds, giving 20 % of oil to the ton of shale, although they had a super-abundance of sulphur, probably 7 %.

As far as he could see, a great number of people had lost large sums of money in connection with the oil industry generally, not because the projects were unsound, but through sheer mismanagement. The mismanagement had been allowed to continue; whilst statements were made in order to raise money on debenture and second debentures, and "boomed" the market, the concerns eventually collapsing and Receivers being appointed. If the Government wished to assist the industry it should see that the Public were protected, and that the money was expended in a judicious manner. He deplored the statement he often heard made in London that people from overseas had "taken down" people in London. As a matter of fact, the people overseas had nothing whatever to do with such concerns. They were clever enough to know a "good thing" when they saw it, and to hold on to it.

The Chairman, in closing the discussion, said the lecturer had made the statement in one part of his paper that "big results can never be expected without large and courageous efforts." One of the great failures in connection with scientific development in this country was that in almost every case efforts were made to start an industry with too small a sum of money. Whether it be in the chemical industry pure and simple, which was the particular industry with which he was more cognisant, or the industry under discussion, that was a fatal error. One of the things which had made for success in the development of German industry was that, in connection with the enormous development that took place in that country between 1870 and the date of the war, sufficient money could always be found to develop things on a large scale. When the Germans came across a proposition such as the manufacture of synthetic ammonia or nitrogen from the air, they tackled

the problem on a scientific basis; they spent anything from a quarter to half or one million pounds on it, after having convinced themselves, by laboratory experiments, that the proposition was a feasible one. If English people spent enough money they could solve such problems. Exactly the same was the case in connection with synthetic indigo. In this country such things were dealt with in a hole-and-corner manner by a very small syndicate, due to the fact that the men who put up the money for the preliminary syndicate were scientifically ignorant and could not realise that they were tackling a big proposition on far too small a scale. It was, after all, merely another way of stating the fact that in Germany the whole population, including financiers, were scientifically better educated than the people of this country. They had a scientific insight into things, and they appreciated to the full the value of expert evidence.

In another portion of his paper the lecturer stated it was desirable that this country should have greater educational facilities for the development of oil technology, and most of the speakers who had joined in the discussion had emphasised that point, but the fact remained that a large number of the people concerned with the industry did not want a real expert who told the truth—that was the last thing they wanted. The statement was frequently made to a real expert: "Will you get out a report on this basis? The works will be put at your disposal, and you will tell us exactly what you find. Let us know what your fee is. If what you find is such as can be published in a prospectus, we will pay you five times your fee." That was quite a customary state of affairs, and in such a case it was presumptive evidence that the people desired a report which would enable them to make, not a success of the concern, but money, to enable them to handle shares which they could pass on to the unsuspecting public at a profit. It was the gentleman whom the lecturer had called "the Bodega promoter" who had in the past done so much to damn the possibilities of the development of scientific industries in this country. In that connection he need only refer to the millions that had been spent on wild-cat schemes for the utilisation of peat. Things that could be proved up to the hilt by the rational expenditure of £5,000 had been used as a means for spending £500,000, a large proportion of which went along "by-ways." We had had some very striking examples of that in connection with the subject of low-temperature distillation. The somewhat caustic remarks made by Mr. Fell were perhaps only justifiable on the ground of what it was known had happened in reference to some low-temperature distillation

projects, which must be fresh in the minds of all the members. Those particular instances, however, were probably cases where the people did not wish to have the technical knowledge that was available had they cared to go to those sources where correct information was to be obtained. It was rather hard to blame the technical expert for not having catholic and very wide knowledge in one person. That was not to be expected, but there were in this country experts who had the desired knowledge if people were willing to go to them, and to take their honest and unbiassed expressions of opinion, and were willing to provide them with sufficient means to enable them to carry out those semi-commercial experiments which were necessary to solve all those factors which must be taken into account before work could be proceeded with on a full commercial scale. It was there that most things broke down. A little syndicate with £3,000 or £4,000 desired to institute a new oil-cracking process; they did so with ½-in. tubes, and were astonished to find that the results were not satisfactory when the work was transferred on to a large scale. It was not due to the fact that the technical knowledge was not there, but simply that the people who provided the money did not realise that the right technical people must be called upon for advice, and that that advice must be followed.

The only other point to which he desired to refer was the remark the lecturer made with regard to the subject of Directors: "Everything had been carefully arranged, the prospectus printed with a first-class board of directors." Speaking in that room on a previous occasion to a very much larger audience, he ventured to state that one of the failures in this country in connection with the development on a large scale of technical commercial processes was our failing in the direction of taking on the Board a majority of people who were quite estimable, honourable, upright gentlemen, but whose prime qualification for their position was that they knew nothing whatever about the subject in any single one of its aspects.

If prior to the war a Company had been formed in Berlin for the manufacture of synthetic ammonia or nitrogen from the air, and the statement was made that the Board consisted of some of the hereditary Grand Dukes of some of the innumerable small principalities of which Germany was made up, would the German public have provided money for the purpose? The Germans as a nation were too scientifically educated to allow a mere title or a mere handle to lead them by the nose. They would immediately ask who was the great expert on the subject of the manufacture of ammonia; were any of the people connected with the Hoechstfabrik

associated with it; was the Allgemeiner Electrik Gesellschaft connected with it? If they were, they would consider the proposition.

But in this country the Boards too frequently consisted of people who were mere figureheads, and he believed that the gradual technical education of the population would lead to a revision of feeling in connection with that matter. In the future the people in this country would ask whether the gentlemen on the Board understood the subject, and whether they were likely to spend the shareholders' money in the proper way.

Mr. Montagu Summers, in reply, said the remarks the Chairman had made in connection with Directors of public Companies were undoubtedly true some years ago, especially at the period of the Whitaker-Wright boom. But the public were now better educated on this subject, and could obtain more reliable information. It was not so easy to rig the markets now. Titles on a prospectus did not now attract the public. The most attractive name on a prospectus nowadays was that of a well-known successful business man, more particularly if the company was a local one connected with, say, Birmingham, Manchester, Glasgow, or any of the large provincial towns.

It was also perfectly true that the Germans were better educated scientifically than the people of this country, and the same remark applied to the people of the United States, in consequence, in both cases, to the exceptional attention given to the subject by the Governments of those countries. It was far easier to obtain capital there for the initial stages of any enterprise, whether connected with a scientific discovery or an invention, than in this country, where one of the most difficult things to obtain capital for was an invention.

For instance, nobody would put up the money to start the manufacture of the cash register in this country in its earliest stages, so it went to America, and the Cash Register Company was now so large and successful that it had the biggest brass foundry in the world simply for making the cases alone of their machines.

Petroleum for medicinal purposes, before the war, came from Germany, a million pounds' worth per annum of this article being imported into this country. The method of making it tasteless and odourless was discovered in Germany after an expenditure of £180,000, the money being put up by the Government through the banks. It would have been impossible to get that done in this country. It was true that a British firm had somehow, since the war, obtained the secret of the manufacture, previously possessed

exclusively by the Germans, and it was now being made in this country.

He could not entirely agree with the remarks Mr. Fell had made. Mr. Fell probably spoke of what he knew twenty years ago, and he could assure him that that state of affairs did not exist at the present time. Some very bad things were brought over from Australia on which the British public lost their money; on the other hand, there were some things brought over, of which the Australians did not think well, but which ultimately turned out to be very good things, and out of which the British public made a lot of money. One instance was the Great Boulder Gold Mine, to-day one of the best in the world, and which has already paid over £1,000,000 in dividends.

He quite agreed with the remarks Mr. Brown had made in reference to the Government. He hoped the Government would take a broad view, not only of large enterprises, but of some of the smaller enterprises which needed support. He maintained that Institutions were urgently required in this country, similar to those existing in America and more particularly on the Continent—a kind of Industrial Bank—not exactly a Bank as understood in this country, but which employed their own experts, to whom any project for which money was required could be referred.

If a business man in this country did not understand a thing he generally paid a clever specialist a fee for information on the subject, and that was the procedure adopted in Germany by their Banks.

The Banks in Germany had their experts for everything, and why could not Commercial Banks in this country be run on the same lines? It ought to be possible for a man with a sound project to go to a Bank and say: "I can only find £1,000; I want another £10,000; will you put your expert on to it, and tell me whether you can advance the money?" Such Banks would occasionally make losses, but the business transacted would be done on such terms that those losses would not amount to more than, say, 2 to 5 % on the dividends paid.

There was nothing in this country between the great joint stock Banks, which would lend perhaps, as a great favour, £4 on a £5 note, at 5 % interest, and the money-lenders, who would not look at anything unless they got 100 %.

On the motion of **The Chairman** a hearty vote of thanks was accorded to Mr. Summers for his most interesting paper, and the meeting terminated with an announcement by the **Hon. Secretary** that it was proposed to hold an Institution Dinner on March 25th.

Thirty-Seventh General Meeting.

This Meeting was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday, 18th March, 1919, Mr. Charles Greenway (President) occupying the Chair.

The Members of Council present were Mr. H. Barringer, Dr. A. E. Dunstan, Mr. Arthur W. Eastlake, Dr. W. R. Ormandy and Sir Boverton Redwood, Bart.

A message of regret for unavoidable absence was received from Dr. F. Mollwo Perkin.

The following paper was read, illustrated by many lantern views, etc.:—

Plant used in the Percussion Systems of Drilling Oil Wells.

By Maurice A. Ockenden, F.G.S., M.I.Mech.Eng., *Member*, and Ashley Carter, A.M.I.Mech.Eng., *Associate Member*.

Introductory.—In the "sixties" and "seventies" of the last century, the *average* depth of oil wells appears to have been about 150 ft.; ten years later it increased to a depth of 400 ft.; at the beginning of this century it was about 1,000 ft.; to-day the world's *average* is something over 2,500 ft. This steady increase points to still deeper drilling in the near future, and an increase in the cost, unless wells can be drilled rapidly, with a minimum of pipe. Pipe is always the heavy item of expense in oilfield equipment. The more rapid the process, the greater the skill required. The most satisfactory wells are those which have been drilled rapidly, with the minimum number of strings of casing. These remarks do not, however, apply to pioneer bore holes, which must be put down cautiously, and with what may, perhaps, prove later a lavish use of casing. With the increase of speed, there must be greater hazard, and the possibility of fishing operations, which, however, have always to be faced.

There is an absence of superficial finish or display in oilfield equipment, which is countenanced by the mining engineer. The engineer, trained in technical schools and shops, perhaps with only home experience, cannot at first grasp the importance of a drilling unit or outfit in an established oilfield, and the greater importance of a pioneer outfit or rig. He cannot realise the problems which constantly arise, and which must be largely solved by the sense of touch, all operations below the surface being out of sight, and confined to the smallest possible space at depths varying from a few feet to over a mile. Many wells are now drilled a mile in depth, and not a few to a mile and a quarter.

It is not intended, nor is it possible, to describe or criticise drilling methods (although there may be some unavoidable references). The authors feel some diffidence in submitting this paper, as the valuable contribution by Mr. William Calder to this Institution (vol. i, pp. 228–279, 1915), entitled "Oil Well Engineering," partly covered the same ground. They desire to draw attention to the necessity of extensive experience in those who undertake *pioneer* borings in new territory. Much responsibility necessarily rests upon those who select sites for the test borings in countries where the geological structure is doubtful or practically unknown. Equally important is the selection of the engineer and drillers to carry out the all-important first well or wells, which will encourage or condemn further operations, and prevent waste of money. The expectant investor necessarily relies upon his advisers (geologists and consulting engineers), as to procedure, but, unfortunately, some technologists consent to the drafting of the specification for the plant and pipe peculiar to their own limited experience, or depend upon the manufacturer to draw up a document based upon brief statements of local conditions, and then, and not till then, a competent driller or engineer is selected and expected to carry out this all-important undertaking, with plant chosen for him. Manufacturers of machinery, rope, tools, pipe, and all supplies should be held responsible for the quality and construction of material furnished, but not for the manner in which they are used. They should, however, keep in touch with operations in all fields of the world, or, at least, with their customers, and so be prepared to improve, as necessary, existing designs, to meet particular local requirements. It is, perhaps, natural that some manufacturers with works and staff adjoining oilfields should be influenced by local surroundings, and the problem in foreign lands is a matter not always realised. There is need for greater co-operation between the consulting engineer and manufacturer, with the field management.

The first drillers of newly-discovered oil or gas wells necessarily influence, if they do not actually establish, the system or fashion of drilling. The driller is usually engaged on a short-term contract, and thus becomes the originator of tools and appliances, which in all probability he himself would not approve, were he to return when the field has reached the producing stage. It is difficult, however, to effect changes even when conditions justify modifications. Local skilled or semi-skilled labour soon becomes established, and minor industries flourish, based upon the methods originally introduced. Therefore, specifications of plant to suit

certain known and established fields, cannot always be regarded as ideal for prospecting in unknown territory. Each particular system possesses its advantages, and it is urged that local conditions be carefully studied before large sums of money are laid out in the purchase of machinery and supplies.

Historical.—The boring of wells is an ancient practice, so old that no dates can be fixed of the earliest methods. The Chinese were evidently boring deep wells in search of salt springs when Julius Cæsar went to fight the Gauls. There is at present in Amsterdam a narrative published by the Jesuits in the 17th century describing the Chinese methods of boring " by an iron hand hung from the end of a cord." The earlier plants were operated by manual or animal power, and while there is some doubt as to when the first drilling rig was built, the Chinese used crude machines before the Christian era. The derrick was made of bamboo poles in the form of a tripod. Into the upper ends of two of these poles wooden pegs were driven, on which was supported the shaft of what is, in present day practice, the sand-line pulley. This reel was made of a log of smooth wood. The sand-line was made by pleating strands of Manila fibre or bamboo leaves, and as the hole was deepened other strands were added. Just below the sand-line pulley, two other similar wooden pegs were driven into the tripod poles. These fulfilled the function of carrying the present-day equivalent of the crown-pulley. The drilling cable was similarly constructed to the sand-line. It would seem that Colonel Drake in 1855 adopted the method of the ancients, and ignored the more advanced European method of that time used by water-well drillers. The application of steam power to the Chinese method, and the large number of wells drilled, with the army of skilled well drillers created by the development of the oil industry, resulted in the present standard cable rig. In Drake's time it is interesting to note that jars or slips had already been introduced and were in regular use by the brine-well sinkers. The accredited inventor was William Morris, who in 1832, made " slips " for two drillers at Kanawha Salines, Va. He never patented his invention, and received no pecuniary advantage from it, but as a public benefactor it is claimed that he deserves to rank with the great inventors. The drilling in Pennsylvania necessitated what were at that period regarded as heavy bits, but there were practically no casing troubles, as were experienced in later fields. It would seem that it took thirty years for the Pennsylvania drillers to understand and overcome the casing difficulties which they experienced when entering the deeper fields of West Virginia.

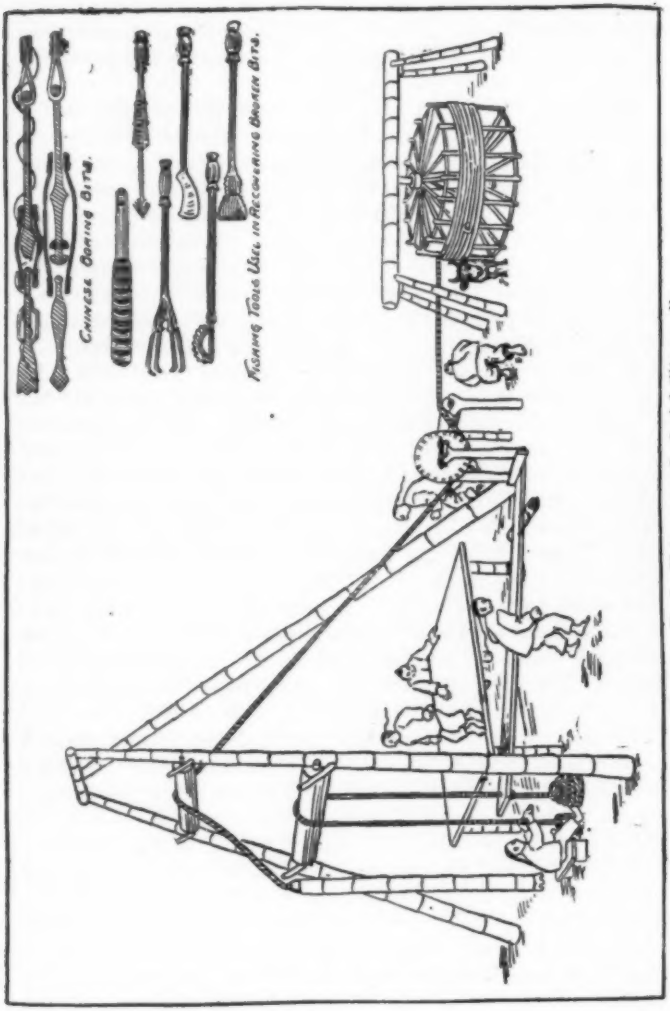


Fig. 1.—Early Chinese method of drilling wells.

The Mannington field was one of the first deep fields, and certain tools and supplies are now quoted as "Mannington" pattern, to indicate heavier material than the earlier lighter Pennsylvanian type.

The Pennsylvanian drillers sent out of their own State for the search of oil, based their experience entirely on their home training, and had little or no knowledge of the softer and more difficult formations. The present American cable rig, therefore, has been evolved by the experience gained from the early Pennsylvanian and Virginian brine well drillers.

Well-boring appliances received little attention in America before Drake's first oil well, in consequence, doubtless, of the limited

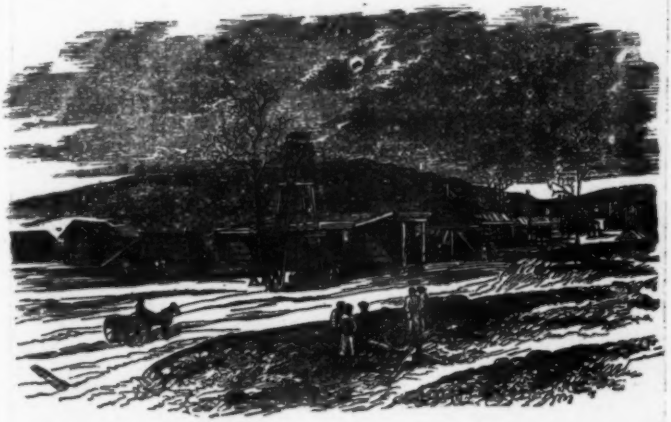


FIG. 2.—General view of an oilfield in Pennsylvania during the "sixties."

demand for water wells or mineral test-borings. The first American oil prospectors ignored the established water-well methods of Europe. French engineers were boring larger and deeper wells before Drake's effort. The Grenelle boring at Paris was in its day considered an accomplishment. This was drilled through the soft beds of the Paris basin to a depth of 1,794 ft. It was commenced in 1784 and reached 560 ft.—then Mulot, a French driller, resumed drilling in 1833, and reached 1,794 ft. in 1841, obtaining a flowing well from the Lower Green-sand.

To illustrate the progress of drilling methods, an artesian well was completed during the Paris Exposition in 1900, as an exhibit in the Bois de Vincennes. The work was carried out with an

FIG. 1.—Early Chinese method of drilling wells.

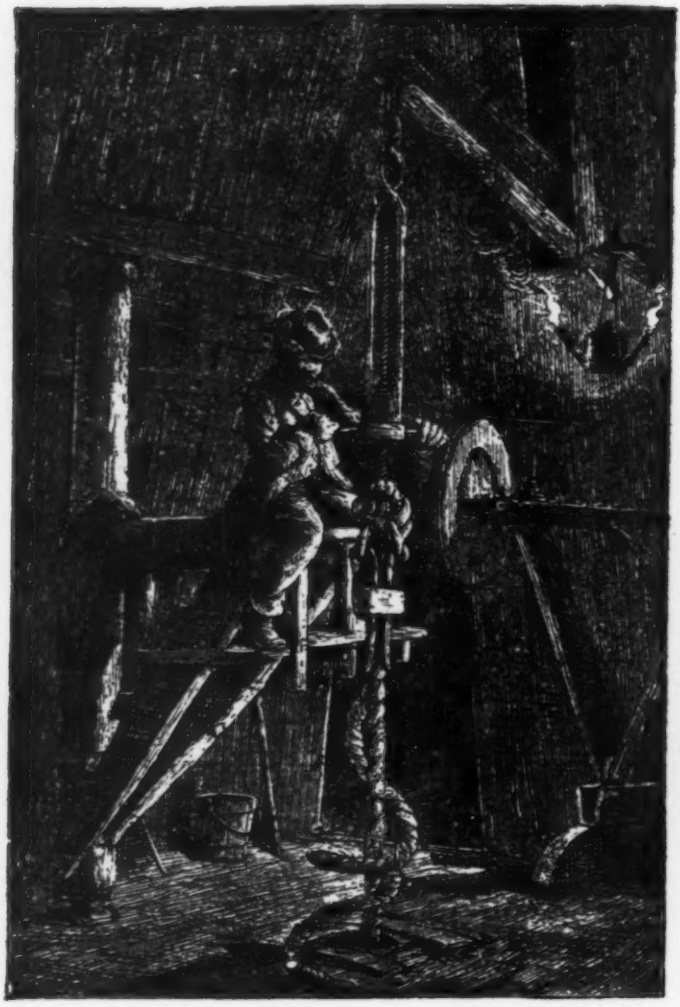


FIG. 3.—Drilling a well in Pennsylvania about 1860.

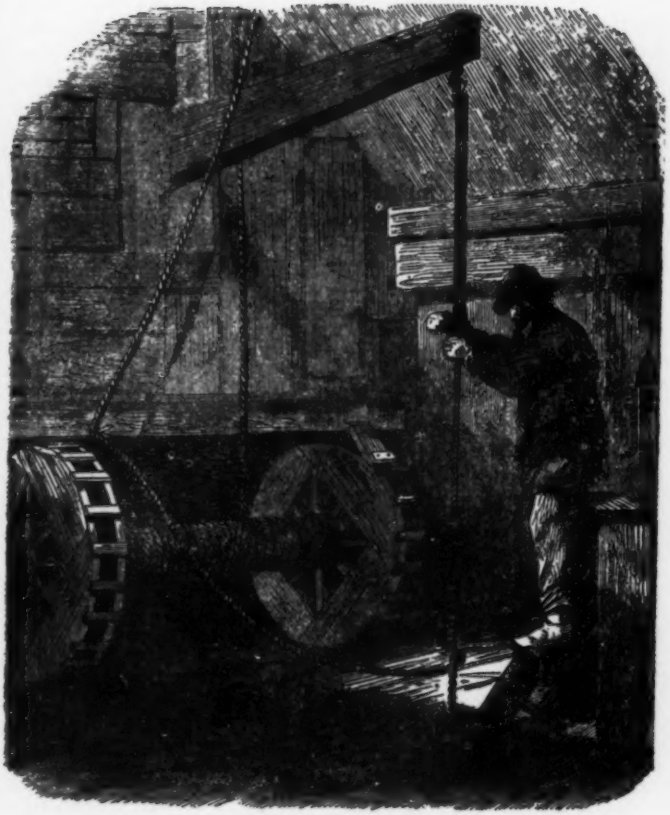


FIG. 4.—A Pennsylvanian driller about 1870.
(Note the construction of bull wheel.)

American standard cable rig, and although the progress was interfered with by visitors and the Exposition authorities, the work was accomplished during the summer months. The French were the originators of modern Canadian boring methods.

The tools used by Drake were exceptionally crude, as compared with present-day plant, although they represented a big advance on those previously employed. The temper-screw was provided with a $\frac{3}{4}$ in. diameter "V" threaded screw, and measured about 3 ft. over all, as contrasted with present-day practice, where we find a screw of 2 in. or 2·5 in. diam., and with a "let out" of upwards of 6 ft., the apparatus being fitted with ball bearings. The tools were provided with parallel joints $1\frac{1}{2}$ in. diameter, and the threading was very crude when compared with the accurate screwing to which we are now accustomed.

The bits of the 1859 well drilled a 3 in. diameter hole, and were 30 in. in length. The entire string of tools did not exceed 300 lbs. in weight, whilst the present ordinary string of 8 in. tools weighs about $1\frac{1}{4}$ tons, and the commencing string slightly under 2 tons.

Thirty years ago a wing rope-socket was in use, the cable being inserted between the wings, which were provided with holes for the purpose, and secured by a riveting iron, riveted over on either side. The bits were made from iron forgings, steel shod, to give a comparatively hard cutting surface, whereas, nowadays, they are made of solid steel forged from high-grade material. The weight of the bits was formerly referred to by the quantity of steel welded on in the process of their manufacture.

It is interesting to note the $5\frac{1}{2}$ in. bits usually had from 60/80 lbs., the 8 in. from 80/100 lbs., and the 10 in., the largest size then generally in use, had from 100/120 lbs. of steel in their composition. The draught for the forge fire was provided by hand-worked bellows, where now a steam-driven blower is used. The apparatus for making and breaking tool-joints consisted of a plate of iron, bent to one third of a circle, $\frac{3}{4}$ in. thick $\times$ 5 in. wide. It was drilled to hold the point of the wrench bar when screwing and unscrewing joints.

It was only in 1892 that a wire rope was employed as a sand-line in place of hemp. Bailing was performed by a 5 in. bailer, 19 ft. long, which was not heavy enough to straighten the $\frac{1}{2}$ in. sand-line used, the result being that the friction against the casing caused the wires to be worn through, and the system was considered a failure. A more pliable wire rope of $\frac{3}{8}$ in. diameter met the difficulty, although considerable prejudice on the part of the drillers had to be overcome before the adoption of wire rope for sand-line and casing

became general. With the introduction of the sand-lines, the sand-reel, which had heretofore been made of hemlock timber, was replaced by an all-iron reel, the superior merits of which were at once realised.

With the early, comparatively shallow, wells, nothing larger

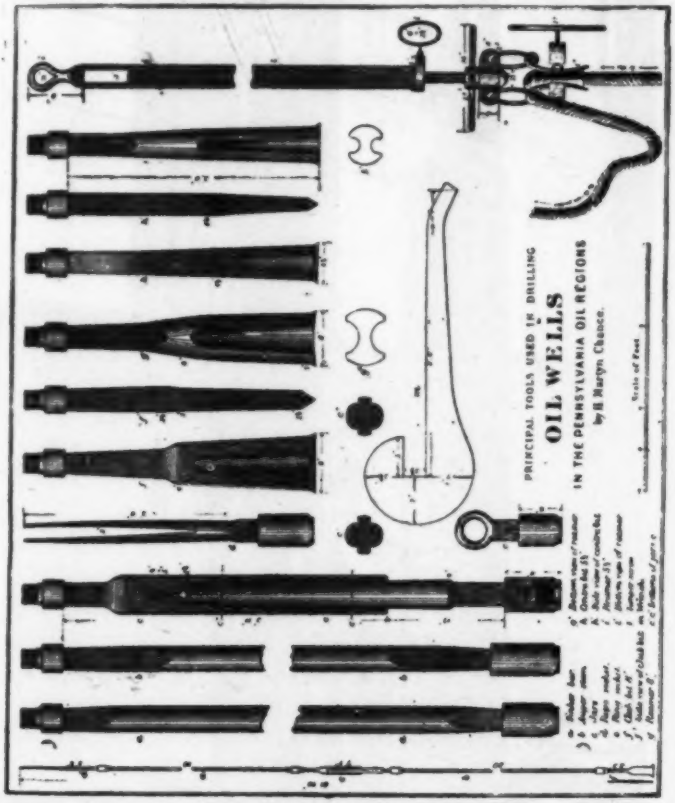


FIG. 5.—Regular drilling tools in use about 1880.
(Note parallel threaded pins, shorter and larger than the earlier pins.)

than 3½ in. rig irons were in use, the weights of the other parts of the rig being of corresponding proportions. The diameter of the band wheel shaft is the governing dimension used when speaking of the size of rig irons.

With increase in the depth of wells, and to meet the heavy duties

demanded of the plant in the handling of casing, particularly that of surging a string of pipe, as is usual in California, the size and weight of the rig irons have been increased, until, nowadays, 7½ in. rig irons are frequently employed.

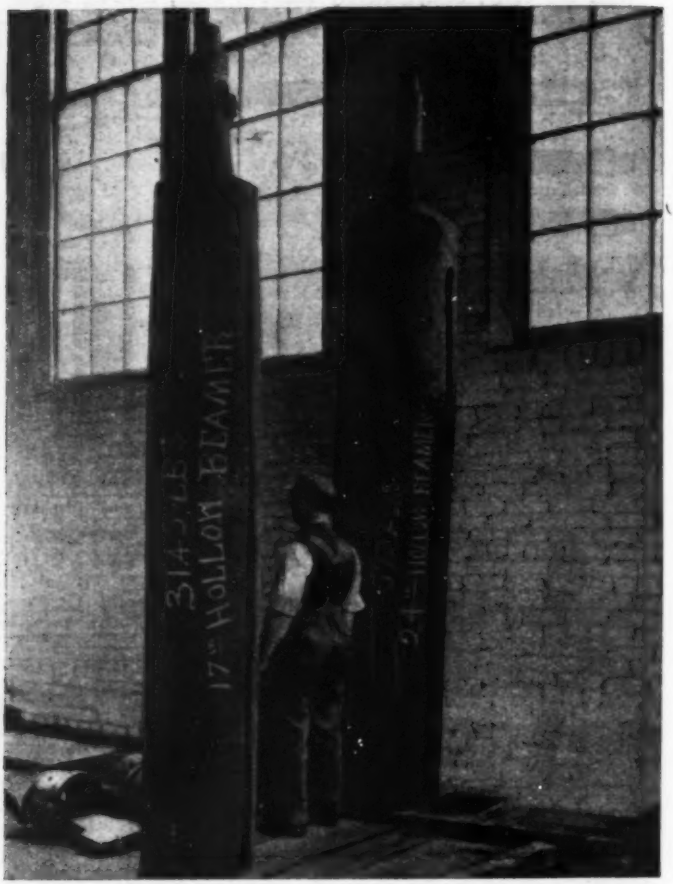


FIG. 6.—Underreamers—17 in. and 24 in.—Typical tools as used in Rumania in 1914.

In the latter part of the last century, lighting was dependent upon spouted lamps, which were not only inefficient, but a source of danger by the use of naked lights. In the present day practice,

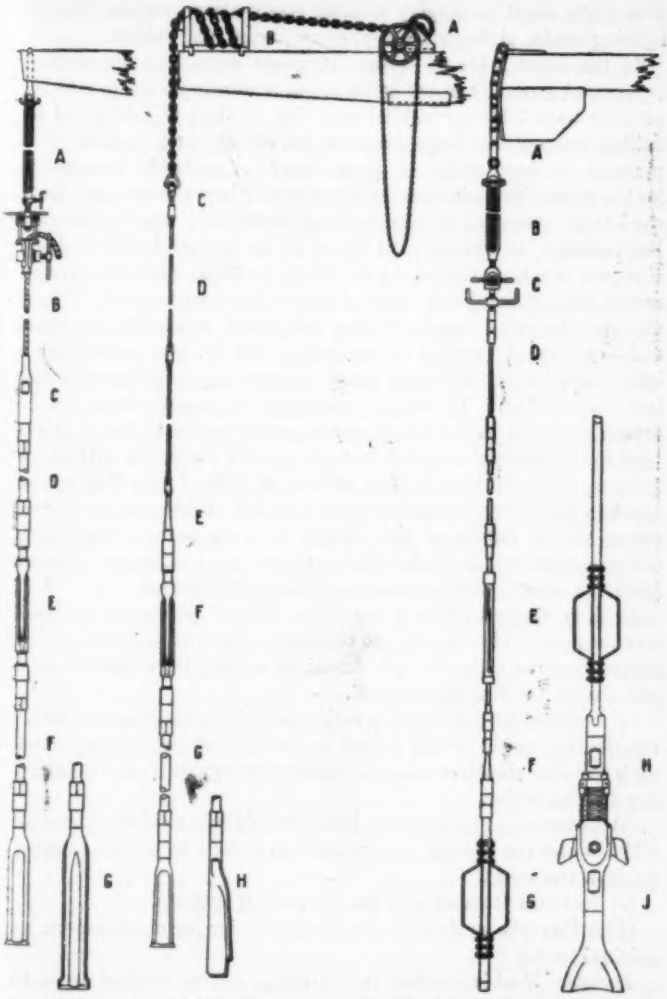


FIG. 7.—Strings of tools of the three recognised percussion drilling systems.

1. American and Californian :—(*a*) temper screw ; (*b*) cable ; (*c*) rope socket ; (*d*) sinker bar ; (*e*) jars ; (*f*) drill stem ; (*g*) bits (standard and Californian).

2. Canadian-Galician :—(*a*) and (*b*) slipper out and chain ; (*c*) swivel adaptor ; (*d*) poles (ash or iron) ; (*e*) adaptor ; (*f*) jars ; (*g*) drill stem ; (*h*) regular and eccentric bits.

3. Russian freefall :—(*a*) flat link chain ; (*b*) temper screw ; (*c*) swivel ; (*d*) poles ; (*e*) freefall ; (*f*) adaptor ; (*g*) sinker bar and guides ; (*h*) under-reamer ; (*j*) drilling bit.

it is quite usual to employ a small steam-driven turbine electric lighting outfit, giving efficiency, convenience, and safety.

In the older fields of Russia, it would seem that the drilling equipment generally in use is the result of development, due to the peculiar native labour conditions. The method of raising oil by bailing necessitates large-diameter bore-holes, and casing. This practice of deep holes of large size was probably responsible for the great disappointment of many would-be reformers, who have used their systems only for wells of moderately small diameter. For instance, to obtain a 14 in. or 16 in. well at 1,400 ft. deep, Russians would commence with 26 in. or 28 in. diameter riveted casing, each string being inserted only a few hundred feet. There was also the delay due to riveting the joints, as against the usual and more rapid practice of screwing. 200 ft. was considered a reasonable length, although many strings only penetrated a few feet collectively. Of course, this type of casing could not be driven or forced in the same manner as the modern type of drive-pipe or casing now adopted in most parts of the world with other systems. The Mather & Platt system of drilling was tried in the Russian fields, but, apparently, it was not considered a success, owing to the failure of the ratchet to work satisfactorily with underreamers, whilst the knives or cutters had a tendency to break from the crown, causing extensive fishing operations.

Drilling Systems.—There are three distinct percussion systems now recognised throughout the oilfields of the world, which can be summarised as follows:—(*a*) American cable; (*b*) Canadian pole and cable; (*c*) Russian free-fall.

(*a*) Represents American practice, and includes standard cable rig, Californian rig (which has all the features of the standard cable with suitable attachments for handling casing, without disturbing the drilling cable).

(*b*) Covers Canadian system, both the lighter type of the Canadian oilfields and the heavier type as used in Galicia as well as in other parts of the world.

(*c*) Includes Russian and Fauck free-fall systems.

(The Fauvelle system is practically no longer employed in its original form.)

Portable Machines.—For test drilling, or for drilling wells to depths not exceeding 1,000 ft., it is considered by some engineers good practice to use a portable machine. Portables in common use are designed after the American cable-tool system, and the machine contains all the essential parts of an ordinary cable rig, with a braced mast, in place of derrick. A separately mounted

boiler of large dimensions is desirable, as the steaming capacity of a small vertical boiler is inadequate for drilling an oil-well. Many portables of the smaller sizes have been used by the Allied Governments during the war for water-well drilling, operated by Colonial and American soldiers.

The "*semi-portable rig*," though frequently and incorrectly termed "portable," is a serious effort to economise the costs in material and labour in erecting. The demand, however, for the semi-portable exists only in certain fields in the U.S.A. and in Canada, where the rigs can be delivered on to a site in practically completed form, and where the handling of casing is not a serious item. There is restricted working-space between the rig and bore-hole. The semi-portable is not suitable for foreign fields, where for transportation the rig must be dismantled, boxed and packed, to be rebuilt at destination. Canadian rigs have been built in portable form, but there is no serious demand for them.

Specifications.—The governing factors, when drafting specifications for oil-well drilling outfits, are:—1, geology; 2, pipe; 3, labour; 4, water; 5, fuel; 6, transportation; 7, production.

1. The engineer should be given full information as to the geological formation to be anticipated, especially known water-horizons, to enable ample provision to be made for suitable pipe.

2. The style of pipe governs the details of a specification, whether drive pipe, casing, California casing or inserted-joint, and of the recognised dimensions and threading.

3. Staff, skilled and unskilled. The engineers and drillers should be selected according to their knowledge in handling casing and tools in a formation similar to that to be penetrated.

4. Such questions as water-supply for domestic use, boiler-feeding, etc., have to be considered with the first well or wells. Pumping outfits are not included in this paper, as water-supply forms a subject in itself. Provision, however, must be made for suitable water, in all prospecting specifications.

5. When oil or natural gas is not available for the initial borings, arrangements must be made for other fuel.

6. Transportation is necessarily an important item in many fields which have either indifferent roads or tracks, but more so in virgin country. It is usual to anticipate rather than to curtail the supplies for a pioneer outfit, even if transportation is difficult and costly.

7. It is most important when a field has been proved or established by the sinking of a number of wells that specifications or indents for renewals or periodical supplies should be carefully

prepared or scrutinised by the field management. Modifications, of course, may be desirable to meet proved conditions, but standardisation of all threads should be maintained.

After determining the type of plant to be used, the details of the specifications, for any system, should be considered as :—

a, essential material per well or rig for developed oilfields ;

b, essential material for partially developed fields ;

c, special and extra material for prospecting or for new isolated sites.

a. Central stores for renewals, fishing tools and stock of pipe are usually either on the property or locally available. Large Companies anticipate their supplies by providing a depôt stock. In the American fields companies supplying plant establish local stores, carrying a large assortment of fishing tools, for sale or hire.

b. The same remarks apply as to *a*, only that there may not be the same facilities, and that a larger capital outlay may be necessary per well.

c. This refers strictly to *prospecting* outfits, where everything must be anticipated, especially for isolated sites. Fishing tools alone can be elaborated to represent a very heavy item, but it is usual for the driller or engineer to construct, devise, and, if necessary, make, special tools.

Essential Plant in an Oil Well Rig.

1. Derrick : foundation and base ; derrick proper ; crown blocks.
2. Rig : rig irons (ironwork) ; band wheel ; bull wheel ; calf wheel ; sand reels ; pulleys.
3. Power : engine ; boiler.
4. Cordage : bull rope ; sand line ; drilling line ; casing line.
5. Drill poles : poles ; pole tools ; substitutes.
6. String of tools : temper screw ; joints ; rope sockets ; jars ; stem and sinkers ; bits ; underreamers.
7. Bailers and sand pumps.
8. Wrenches and jacks.
9. Tools for handling pipe : wedge and rings (clamps) ; elevators ; tongs ; drive clamps.
10. Pipe : drive pipe ; casing ; inserted joint ; riveted ; drive shoes and heads.
11. Fishing tools : To recover tools ; pipe ; rope ; rods.
12. Miscellaneous (or extras, as necessary) : blacksmiths' tools ; carpenters' tools and sundries ; water supply ; belting ; electric lighting outfit ; rig housing.

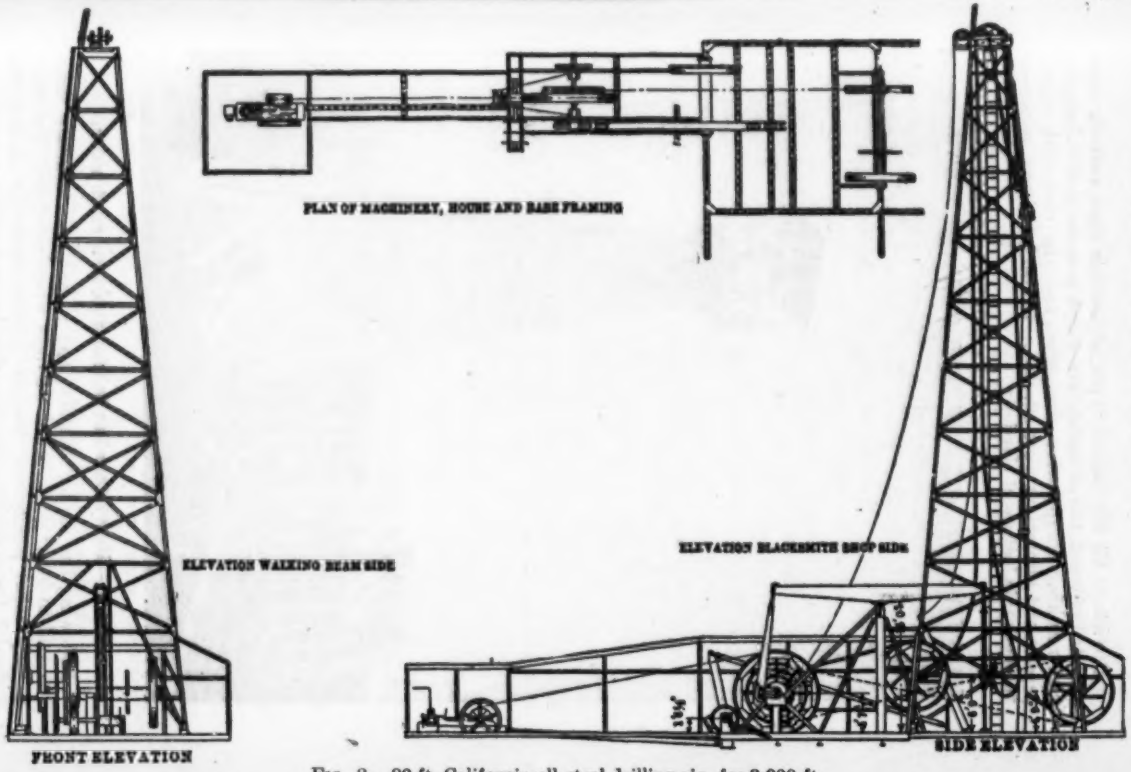


FIG. 8.—80 ft. California all-steel drilling rig, for 3,000 ft.

Derricks.—All the earlier types of derrick were entirely constructed of wood, the advantages of which were its plentiful supply and resulting comparative cheapness, and the ease with which repairs and alterations were effected. It also, of course, possesses the desirable feature of elasticity.

FIG. 9.—Heavy Canadian-Galician rig during construction.

Following the earlier derricks, and in order to facilitate their removal to other sites, bolted derricks were introduced, but only a very small proportion, because a well producing oil requires a derrick for swabbing, pumping, cleaning and pulling.

Structural angle-steel derricks were introduced in the early nineties. Ten years ago the panel-heights, which had previously been 14 to 17 ft., were reduced, as it was found the bracing could be made more effective and of the same strength in the legs obtained by the use of lighter sizes of angles. The steel derrick of to-day has panel-heights of about 8 ft. It was about this time complete steel rigs were introduced, the derrick, crown block, ladder, base, machinery, supports, samson post, jack posts, knuckle posts, walking beam, bull wheel, band wheel and house framing being built of this material. It is unlikely the steel rig will replace the wooden structure, except in certain areas, although sufficient numbers have now been used to prove their superiority.

Tubular steel derricks possess the great advantage of rapidity of construction. The Neill patent is the most successful. Its development is largely due to the introduction of forged steel clamps. The original cast-steel clamps were not uniform in strength, and forging enabled the use of lighter and yet stronger clamps.

The initial cost of a steel rig is greater than that of a wooden, but there are reported cases in which the former have been used for drilling upwards of twenty wells.

Hard woods make excellent derricks, but the operator is not always in the fortunate position of having a plentiful supply at hand, and should he have to use softer woods, it is sometimes necessary to employ double bracing.

The derrick is carried on posts, resting on suitable timber or concrete footings, the latter being unnecessary except in the case of heavy rigs.

The evolution of the derrick can be summarised as follows :—

The spring pole and tripod.

The braced mast, single or double.

The four-legged braced wooden derrick intended for permanent use, built without idea of removal.

The four-legged braced wooden derrick, put together with bolts to permit removal and re-erection.

The pipe derrick.

The long-panel structural steel derrick.

The short-panel structural steel derrick.

The structural steel drilling rig complete, with machinery, supports, wheels, house framing, metallic covering, etc.

Rig.—The construction of the rig varies with each system, but each has the essential mechanism for operating the drilling line, sand line, and, in the case of the Californian, the casing line.

The American standard cable rig consists of a driving wheel,

called the band wheel; the bull wheel and the sand reel. The band wheel is driven from the engine by a belt. Motion is transmitted to the bull wheel by a rope running in a groove on the band wheel. The sand reel is operated by friction-drive off the band wheel. A crank on the end of the shaft of the band wheel operates the walking-beam.

The California rig is similar, with an additional groove on the band wheel (or special sprocket) for drive to the calf wheel or casing wheel, making four separate spools or drums.

The following indicates sizes and weights of American rig-irons standardised throughout the world. The diameter of the shaft, as already stated, always governs the size of the rig-irons :—

Rig Irons.	3½ in.	4 in.	4½ in.	4¾ in.	5 in.	6 in.	7½ in.	
Standard Cable	1,584	2,352	2,666	2,697	2,919	—	—	lbs.
California ...	—	—	4,766	—	4,828	—	—	„
"Ideal" California	—	—	—	—	7,451	7,879	13,214	„

The Canadian rig consists of a compact woodwork frame, with one shaft fitted with two reels or spools for transmitting the motions desired. On the main shaft is provided a pulley for the main drive, which communicates by belting with two spools running overhead in the upper part of the framework. The main shaft is provided with a crank at one end, which, by means of a pitman, transmits an oscillating movement to an overhead walking-beam when the engine is in operation. The band and spool pulleys are flanged to prevent the driving belts from slipping off, as the belts are always left in position loosely, and the spools are operated by jockey pulleys which are drawn inwards by means of levers. One spool wheel operates the sand line, whilst the other is used for raising and lowering the drilling rods. A slipper-out attached to the walking-beam is used for giving the requisite feed when drilling. The chain several times encircles the jacket at the end of the beam, so that when the tools are released by the slipper-out, the greater part of the weight is carried by the beam.

Power.—The motive power used is either steam, internal-combustion engines or electricity. The two latter have already been fully dealt with in papers read before this Institution, viz.: "The Internal Combustion Engine on the Oilfield," by F. G. Rappoport, vol. i, pp. 195–227, and "The Application of Electrical Power to Oilfield Requirements," by J. W. Burford, vol. iv, pp. 229–276.

In the oilfields of America and Canada, notwithstanding the unlimited supply of gas which is allowed to flow to waste and the free supply of oil, the internal combustion engine is *not* used for drilling. Many have long been made, and are still being made,

for oilfield work in the U.S.A., but only for pumping, swabbing, pulling, etc. These engines would be freely used for drilling in preference to the more expensive steam, if practicable.

Steam power is in more general use on oilfields. It is simple in generation and possesses flexibility, so indispensable in the work connected with the various processes of an oil well.

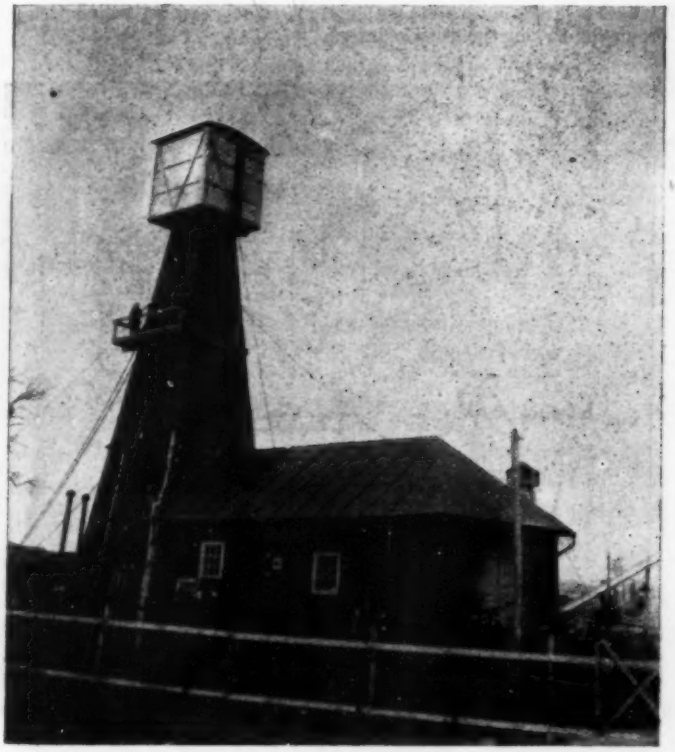


FIG. 10.—Recent type of heavy Galician rig (4,000—5,000 ft.)

The various types of boilers used throughout the world consist of Cornish, Lancashire, Californian and Locomotive. Each field adopts its own type of boiler to suit fuel and local bye-laws. The most usual type, however, is that of the locomotive portable. This is fitted with a dome or drum to ensure dry steam. The pressure

employed is usually 120 lbs. per sq. in., and evaporation up to about 2,000 lbs. water per hour, although in the deep wells of Galicia these figures are exceeded.

The steam engines employed on oilfields are of horizontal, non-condensing, single-cylinder type. They are provided with reversing gear, operated from the derrick, to facilitate the handling of tools and bailers. The power varies from about 15 to 70 h.p. The fly wheel is fitted with detachable rims, which can be added to or removed to suit the duty required.

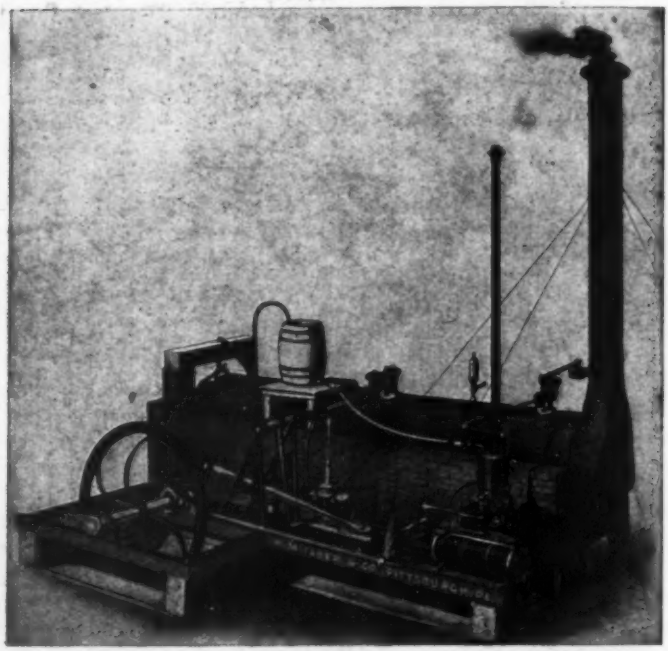


FIG. 11.—Engine and boiler as used by Colonel Drake—1855/59.

Rope and Cordage.—These constitute a most important item in all drilling equipment. The deeper the drilling, the more difficult is the problem of deciding the construction and quantities. As an illustration, the deepest well in the world was commenced with ordinary Manila cables, and carried to a great depth, which was only possible by drilling with a "dry" hole. The following ropes were used in drilling and fishing in this remarkable well :—

Old $2\frac{1}{4}$ in. Manila cable, two lengths of 700 ft. each.
New $2\frac{3}{4}$ in. × 2,800 ft. Manila cable.
$\frac{7}{8}$ in. × 4,000 ft. wire rope.
$\frac{7}{8}$ in. × 1 in. × $1\frac{1}{8}$ in. × $1\frac{1}{4}$ in. × 10,000 ft. tapered wire.
$\frac{7}{8}$ in. × 1 in. × $1\frac{1}{8}$ in. × $1\frac{1}{4}$ in. × 10,000 ft. „ „
$\frac{7}{8}$ in. × 1 in. × $1\frac{1}{8}$ in. × 7,850 ft. tapered wire.
1 in. × 7,000 ft. wire.
New $\frac{7}{8}$ in. × 1 in. × $1\frac{1}{8}$ in. × $1\frac{1}{4}$ in. × 10,000 ft. tapered wire, and used one day only in fishing.
Old 1 in. × 5,000 ft. and 7,000 ft. wire ropes, and used one day only in fishing.

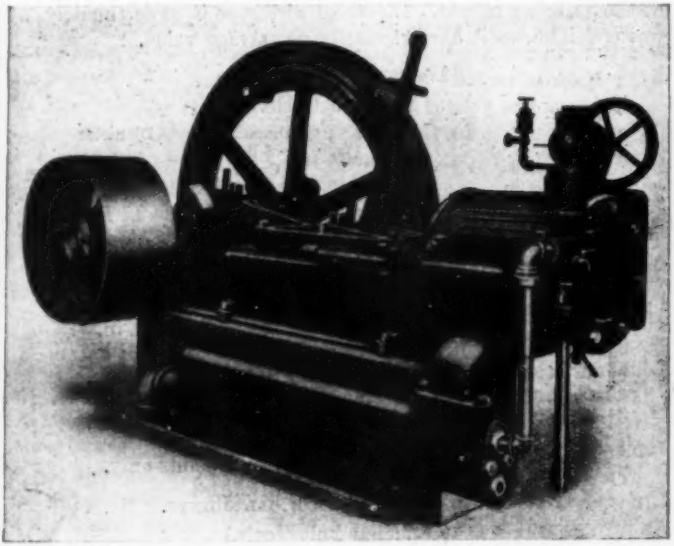


FIG. 12.—Typical drilling engine, showing water heater and boiler feed pump.

It is not generally realised that a considerable amount of cordage, especially wire rope, is destroyed or damaged during fishing operations, which probably impose loads and duties in excess of, and different from, those for which the rope was constructed. This prevents a reasonable estimate as to the average footage to be expected of a cable.

Drake's well was drilled with a rope or cable, and American practice has never departed from this system. Wire rope can be used

in wells with high level fluids with ease, as compared with Manila cable; it possesses freedom of action, when drilling during a flow of liquid at the casing head. Californian conditions were evidently the first responsible for the use of wire rope in cable-drilling methods. The leading wire rope makers in the States struggled with this problem. It is interesting to record that the American drawn wire was found unsuitable, so that for a considerable period, superior English steel drawn wire was imported and fabricated into ropes, which were shipped to oilfields all over the world. A few British wire rope makers had given the subject of oil well ropes special attention, and were supplying many of the oilfields at the outbreak of war. Discarded wire rope is, unfortunately, a wasteful item, as it has practically no salvage value.

STANDARD TOOL JOINTS.

(American Cable.)

Joint.	Wrench Square.	Diameter of Box Collar.	Diameter of Pin Collar.
1⅝ in. × 2 in. ...	2¼ in.	3 in.	2⅞ in.
1⅝ in. × 2½ in. ...	2½ in.	3⅜ in.	3⅛ in.
2 in. × 3 in. ...	3½ in.	4⅜ in.	4⅛ in.
2½ in. × 3½ in. ...	3½ in.	4⅜ in.	4⅛ in.
2½ in. × 3½ in. ...	4 in.	5⅛ in.	5 in.
2⅝ in. × 3⅝ in. ...	4 in.	5⅛ in.	5⅛ in.
3 in. × 4 in. ...	4½ in.	6¼ in.	6 in.
3⅛ in. × 4⅛ in. ...	5 in.	6½ in.	6½ in.
3⅛ in. × 4⅛ in. ...	5 in.	6⅝ in.	6½ in.
4 in. × 5 in. ...	5½ in.	7⅜ in.	7 in.
4¼ in. × 6 in. ...	6 in.	8⅛ in.	8¼ in.

7 flat threads are recommended.

8 sharp threads are used for smallest sized joints only.

STANDARD SIZES OF DRILL JOINTS.

(Canadian Pole Tools.)

Joint.	Wrench Square.	Diameter of Collar.	No. of Threads per inch.
1¼ in. × 1¾ in. ...	1¾ in.	2 7/16 in.	8
1½ in. × 2¼ in. ...	2¼ in.	3¼ in.	8
1⅝ in. × 2⅜ in. ...	2⅜ in.	3⅜ in.	8
1¾ in. × 2⅝ in. ...	3 in.	4⅛ in.	8
2 in. × 3 in. ...	3 in.	4⅛ in.	7 or 8
2¼ in. × 3¼ in. ...	3½ in.	4⅞ in.	7 or 8
2½ in. × 3½ in. ...	4 in.	5⅛ in.	7 or 8
2⅝ in. × 3⅝ in. ...	4 in.	5⅛ in.	7 or 8
3 in. × 4 in. ...	4½ in.	6 in.	7 or 8
3¼ in. × 4¼ in. ...	5 in.	6½ in.	7 or 8

Joints.—In the early days, it was the practice to use parallel joints for the string of tools. This principle was the cause of much trouble, owing to joints becoming worn from frequent making and breaking (screwing and unscrewing), resulting in loose uncertain joints. To overcome this, the taper joint was introduced, which allows of "draw." This great improvement was first adopted in 1880 by Jonah Smith in the Pennsylvanian field.

It is no exaggeration to say that the success of a string of tools depends upon a perfect-fitting joint. Every tool for use in the well is fitted at either end with box and pin. The taper joint has been found superior to the old style parallel threading, and is now almost universally adopted. The measurements are taken diametrically across the narrowest and widest parts of the pin. The pitch of the threads is either seven or eight to the inch, and machined either with sharp ("V") or flat threads. Each joint must necessarily be fitted for the square or flat surface to receive wrenches, hence there are three distinct dimensions to be specified with each joint, i.e.

1. Measurements of the truncated cone, or joint proper.
2. Number and form of the thread.
3. Size of the square for the wrenches.

Example: $2\frac{3}{4}$ in. × $3\frac{3}{4}$ in. — 7 flat — 4 in. sq.

Bits.—There are several forms of bits, the selection being governed by the system in use and dependent on the formation to be drilled. In drilling by the cable system, should the formation be of slate, limestone, or sandstone, it is necessary to dress the cutting edge of the bit more or less to a chisel point, whilst for softer formations, such as clay, shale, and sands, the centre of the bit is hollowed out, making a concave face. In sandy and soft formations a chisel-edged bit will enter faster than the drillings can be mixed with water, thus making it necessary to re-drill, in order to form a slurry for quick removal. Some operators desire thick, wide bits with wide backs, others thick wide bits with hexagon backs, whilst others again use thinner bits, not quite so wide, but with plenty of clearance. Longer bits are becoming more general throughout the American fields, particularly for deeper drilling. They have been made as long as 11 ft. for special work, but 7 ft. and 8 ft. are quite common at the present time. It used to be the custom for the larger bits to be drawn out or forged into smaller sizes, with a view to economy, but now bits are generally used for one diameter only, until worn out. It cannot be too strongly urged, especially for foreign service, that a knowledge of heavy smithing is necessary in those responsible for the operation of dressing bits, as the following examples will show:—

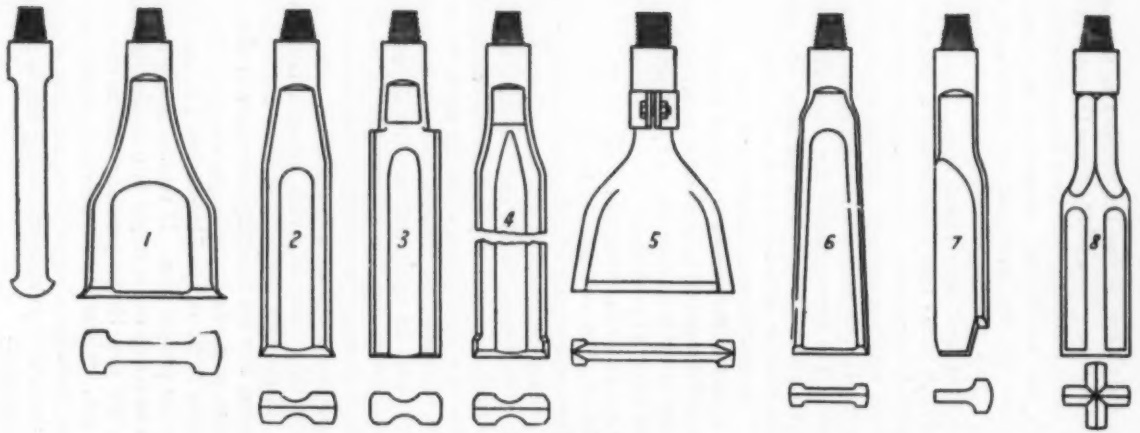


FIG. 13.—Bits.

(1) Spudding bit; (2) regular pattern American bit; (3) Mother Hubbard bit, showing cutting edge on the shoulders; (4) modern long body California bit; (5) Russian bit, with guide attachment; (6) regular Canadian tapered bit; (7) eccentric bit as used with pole tools (Canadian), also with cable tools to a limited extent in California; (8) star bit, favoured by the Rumanian and Russian fields for trimming or rounding a hole, but only used to a limited extent.

Fig. A shows an uneven cutting edge. Bits dressed in this fashion frequently break at the pins, in fact some have been known to break off in the wrench square.

Figs. B and C indicate the result of improper heating and tempering. Large bits, apparently heated and tempered correctly

FIG. 14.—A consignment of bits for Rumania, 1914.
(Note the hexagon backs and deep waterway. Spudding bit on the right.)

will crack after one or two hours from the strains due to uneven heating. Unfortunately, the common practice, when heating large sized bits, is to overlook the necessity of turning the bits, after placing them in the fire, such treatment producing cracks.

Fig. D shows fractures due to the bits being tempered too hard. In such cases they have to be re-forged, wasting time and material.

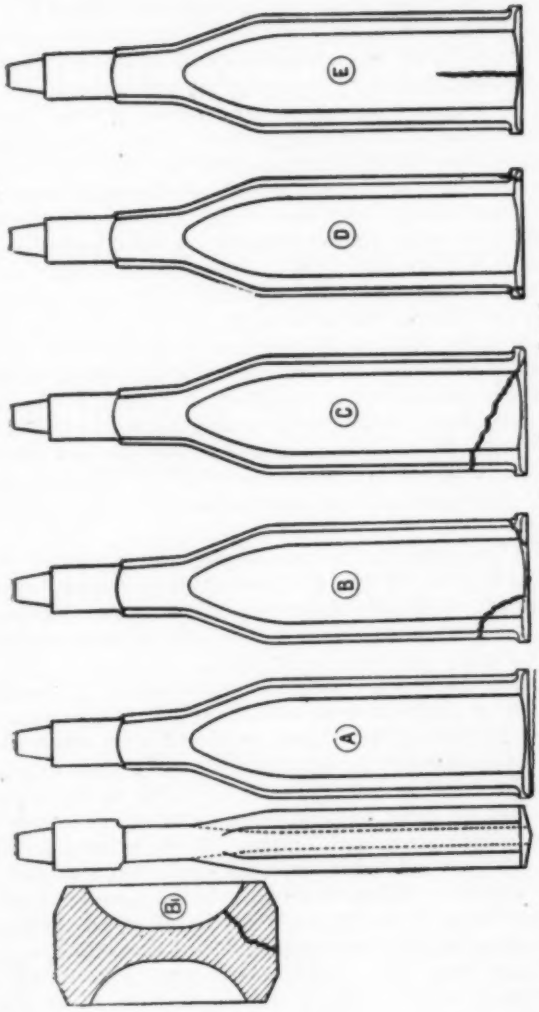
Fig. E indicates a fracture, which, although not common, is occasionally reported, namely, a crack running from the cutting edge up the centre of the water course. Such a crack usually indicates "piped" steel. It should rarely happen, because the steel billet is worked, dressed and tempered at the opposite end to that in which the "pipe" is liable to occur.

Great care should, therefore, be exercised in the manufacture and dressing of bits. If a billet of steel large enough to make, say, one of the heavier California pattern bits, weighing from 1,500 lbs. upwards, is placed in the heating furnace, without pre-heating, it will crack. In forging or dressing a large bit, it should be placed in a very slow fire, and frequently turned. The greatest care should be exercised to prevent the light portion, forming the water-course, becoming heated more rapidly than the heavier, forming the webs, and thus producing uneven strains. Should the bit not crack in the fire, it will probably do so in subsequent tempering.

The above-mentioned remarks also refer to Canadian, Galician or Russian types of bits, although the California pattern is heavier. An eccentric bit is fitted with one large web. Bits which are made of **T** & I section require equally careful forging and tempering. Such bits are used more with Canadian and Galician, although heavy concentric bits have been recently introduced with the California cable-tools for use in certain Californian fields.

The greater depth and the more rapid process of drilling have made it necessary to eliminate the possibility of defective welding. Solid steel bits, as before mentioned, have superseded iron and steel bits.

Jars, which are included in every string of tools, whether cable or pole tool, consist of two links forged from a solid piece of special steel, with box and pin joints. They are not, however, used in drilling with the *free-fall*, as the action of this gives practically the same effect. In drilling, they should be attached to the rope socket above the drill stem, but for fishing operations, it is frequently necessary to place them below the stem, immediately above the fishing tools, to give a heavier upward blow. Originally, when a string of tools was lighter than present practice, a "sinker" was used, as well as an auger stem (to give additional weight) in which case jars were placed between the two. The function of the jars is to liberate the drilling bit, when working in a formation having a tendency to retard the action of the drill. The stroke of the American drilling jar is 4½ in., whilst that of the Canadian and



Bits. FIG. 15.—Defects due to improper dressing.

Galician is 6 in. to 8 in. Fishing jars may have a stroke as long as 60 in., according to requirements. Unfortunately, as with drilling bits, jars are frequently abused by inexperienced drillers.

Fishing Tools.—Numerous standard fishing devices are designed for recovering damaged and lost drilling tools, cutting and removing defective casing, picking up dropped strings of casing, also the recovery of tangled rope, and other purposes, although certain cases demand special tools and application. The authors respectfully suggest that fishing operations could well form the subject of future valuable papers. Although fishing is frequently regarded as part of the training of a first-class driller, there are many operations which require the greatest ingenuity, skill and patience. In well-established fields, experienced "fishermen" frequently assist or take entire charge of difficult operations. For every piece of plant used in drilling a well, some fishing device is either regularly or specially made, with modifications, for complicated operations.

Many fishing tools are now machined out of solid billets, causing a very heavy expenditure in manufacture, simply to eliminate possible weakness in welding. All material inserted in a borehole should be of the highest quality. One defective unit may destroy the efficiency of the whole. Inferior or maltreated rope has caused the loss of many promising wells, and thousands of pounds in fishing operations.

Casing.—The question of casing is of such great importance, and its varieties of joints, threading and weights so wide, that it is not possible to refer to it more than briefly in this paper. The word casing is a general term covering all pipe used in lining the walls of a borehole.

Every well requires some casing in its construction, the quantity and number of strings varying with the depth, the irruption of water, and caving troubles. There are several forms which may, however, be divided into three categories, namely, those in which a coupling or collar is used; those in which the several lengths are connected by being screwed into each other; and those in which the lengths are riveted together. Casing screwed to butt in the couplings is called *drive pipe*, and, as its name implies, is especially suitable to withstand driving, the full area of the metal of one length being in direct contact with the full area of the metal of the adjoining length. The common practice is to use drive pipe for the larger sizes only. The drive-pipe joint, screwed with a thread to meet in the centre of the coupling, cannot be made sufficiently tight to exclude the great pressure of gas and water met with at low levels. Hence deeper drilling with greater pressures

FIG. 16.—Various types of casing.

(1) California casing—long collar; (2) standard casing; (3) drive pipe; (4) inserted joint casing; (5) swelled and creased casing; (6) flush joint casing; nos. 5 and 6 are *not* and *should not* be used in oilfield work, for which they are entirely unsuitable.

has developed special casing joints. *Standard casing* is so constructed that the lengths do not butt together, and is, therefore, not so suitable for driving. *California casing* couplings are much longer than those of the standard casing, and the pitch of the threads is finer. It is obvious that fewer strings of casing with couplings can be telescoped than with *inserted joint* or *riveted casing*. As it has already been remarked, the importance of the pipe selected

FIG. 17.—Large riveted casing (Baku, Russia).

cannot be overstated, as it governs the specification or system adopted.

Russian Free-fall.—The authors hesitate to submit a detailed specification of Russian free-fall tools, as there have been many modifications during the past few years, and it is highly probable that other systems will be eventually adopted. The tools, weighing about 1½ tons, consist of a bit, underreamer, sinker bar and the

free-fall mechanism, these all being connected by square iron rods to the temper-screw and walking-beam. The rods are usually 21 ft. long and about 1¼ in. square. The rig machinery operates the walking-beam for raising or lowering the rods and tools. A second hoist or drum controls the sand pump, and a further drum is used for the casing lines. Thus there are practically the same three functions as in the California rig, but with the slower process of raising and lowering the solid rods, which require a larger staff in attendance. The action of the mechanism called "free-fall" is as follows: The rods with tools attached are first adjusted to reach the bottom of the hole. Each downward movement produced by the walking-beam causes a spindle inside of the free-fall (to which is attached the underreamer and bit) to engage with a projection on which this spindle is allowed to rest during the upward movement. By rotating at the temper screw, the spindle, with underreamer and bit attached, is released and falls free of the main string of rods, a drop of about 4 ft. The free-fall mechanism again engages the spindle on the upward movement. Owing to the cumbersome gear used in the Russian wells by this system, and the larger diameter of the holes drilled, it can be easily understood that fishing operations present many serious problems, and greatly retard progress. The cost and the speed of drilling compare unfavourably with other recognised systems.

The Circulating System, which is illustrated in Mr. Calder's paper, consists of a string of California percussion tools, with the addition of a circulating head, to allow of water (or mud) being pumped under pressure through the centre string of casing, during drilling operations, and the fluid passing up behind the casing, so as to enable the pipe to remain free to follow the tools through treacherous casing strata.

Conclusions.—It is hoped that sufficient has been stated in this paper to indicate that, however well designed any plant in the oilfield may be, especially for drilling operations, the ultimate success of the undertaking largely depends upon the knowledge and skill of the staff employed. The problems in drilling are frequently of a varied character, especially in pioneer borings for oil and gas, and the work should encourage young men to take an interest other than in the mere knowledge of making a hole by mechanical means.

It is claimed by some that it is not the trained engineer who succeeds in drilling. Men are generally selected for their good judgment, blended with courage and caution, who can, when in trouble, exercise ingenuity, patience and initiative. Englishmen have not taken seriously to this class of work, probably because there

have been in the past insufficient means for home training, and little inducement to the younger men to go abroad in a minor capacity.

Mr. Dalton refers to this subject in his editorial "Technical Investigation," p. 2 of this volume:—

"This is possible within the United Kingdom for nearly every industry, but in respect of the technology of raising petroleum and securing supplies of natural gas, study on the spot is not practicable at home. We can show neither gushers nor pumpers, and fishing jobs at 3,000 ft. would need a hole drilled for educational purposes, and intentionally obstructed. Nor do the oilfields of the Empire afford as wide a range as could be desired of the conditions under which petroleum is found. For the desired purpose of education, productive fields are necessary in which new drilling is constantly in progress, and which collectively cover every variety of geological and stratigraphical conditions—alternations of rocks of varied coherence, and of impervious and waterlogged strata, with every angle of dip, and every degree of pressure in fluids encountered, besides other sources of difficulty in boring, whilst the dimensions and system of plant show similar variety in correlation with the natural character of the fields."

It is not uncommon to find men entrusted with pioneer drilling who have only had home experience. Boring logs disclose varying records of drillers' work, under similar conditions and using the same tools. A good driller should adapt himself to conditions, however difficult or different from his earlier experience.

All concerned in the drafting or interpretation of specifications find some difficulty in selecting suitable nomenclature: slang and local expressions are largely responsible for the present terminology. This difficulty is increased when translating into foreign languages. Every industry coins its own peculiar terms and expressions. To prevent misunderstandings, and to facilitate interpretation by ordinary English-speaking and foreign engineers, some form of standardisation of trade terms should be adopted.

The authors wish to acknowledge Mr. Albert Millar's kind assistance in the preparation of the Galician specification (No. 4), and for the loan of photographs.

It is obviously impossible in any paper of this nature to give details of all items of plant for any system of drilling, but the following typical specifications include the essential material.

1. American cable rig for 2,000 ft.
2. America-California rig for 4,000 ft.
3. Canadian rig for 2,000 ft.
4. Canadian-Galician rig for 4,000 ft.

Specification No. 1.

American (Standard) Cable Rig for 2,000 ft.

The following is a typical specification of Pennsylvanian or standard American practice for drilling in formations which are more or less free from caving tendencies, or where the handling of casing or pipe is not a serious problem. Standard drive pipe and casing are used with this specification. Diameters of tools and casing can be changed, if conditions are favourable. An additional string of both may be included, should unforeseen difficulties require a further reduction.

Derrick.

A standard tubular or steel derrick should be provided, not less than 72 ft. in height with 20 ft. base; otherwise a specification for timber and lumber should be added.

Rig Iron Outfit.

1 4½ in. shaft and crank complete.
1 pair 4½ in. flanges, keys and bolts.
1 round iron stirrup.
1 set 4½ in. centre irons.
1 set 4½ in. bowl gudgeons.
1 set 4½ in. bowl gudgeon bands.
1 30 in. derrick pulley.
1 24 in. sand line pulley.
1 ¼ in. × 9 in. × 28 ft. brake band.
1 10 in. × 10 ft. back brake.
1 1¼ in. × 9 in. × 9 ft. brake lever.
1 9 in. brake staple.
40 1 in. plain band cants, 10 ft.
8 2½ in. plain bull wheel cants, 96–1 in. plain bull wheel cants.
16 2½ in. grooved bull wheel cants, 16–10 in. oak bull wheel arms.
32 Bull wheel handles, 8–2½ in. plain tug cants.
24 1 in. plain tug cants, 16–2½ in. grooved tug cants.
1 Oklahoma pattern iron sand reel, 1,200 lbs.
300 lbs. wire nails.
8 ⅞ in. × 18 in. D.E. bolts.
14 ¾ in. × 20 in., 10–¾ in. × 18 in., 4–¾ in. × 16 in., 4–¾ in. × 14 in., 10–¾ in. × 12 in., 12–¾ in. × 10 in., 8–¾ in. × 8 in., 8–⅞ in. × 18 in. machine bolts.
70 ¾ in. W.I., 36–¾ in. and 16–⅞ in. cast iron washers.

If Oklahoma pattern iron sand reel is not desired, a 40 in. oak head and oak shaft wood sand reel can be substituted.

Machinery.

1 Steam boiler capable of evaporating with ease 1,500 lbs. of water per hour at 100 lbs. steam pressure with fuel found in the district, fitted with injector and spares.

1 10½ in. × 12 in. horizontal link steam engine, with pulley and fly-wheel, feed pump and feed water heater, with means for operating both throttle valve and reversing gear from the derrick, and spares and belting.

Cordage.

2 2½ in. × 2,000 ft. Philadelphia Manila cable.
1 2½ in. × 85 ft. bull rope.
2 ½ in. × 2,500 ft. wire sand line.
1 1 in. × 500 ft. wire casing line.
1 1 in. × 40 ft. endless wire dead line.

Drilling Tools.

1 5 in. × 32 ft. auger stem, 2¾ in. × 3¾ in. 7 flat I. & H. pin, 3¼ in. × 4¼ in. 7 flat I. & H. box.
1 4¼ in. × 34 ft. auger stem, 2¾ in. × 3¾ in. 7 flat I. & H. 4 in. square (box and pin).
1 16 in. spudding bit 3¼ in. × 4¼ in. 7 flat I. & H. 5 in. square.
1 set 13 in. nom. all steel bits, 3¼ in. × 4¼ in. 7 flat I. & H. 5 in. square.
1 set 10 in. nom. all steel bits, 3¼ in. × 4¼ in. 7 flat I. & H. 5 in. square.
1 set 8½ in. nom. all steel bits, 3¼ in. × 4¼ in. 7 flat I. & H. 5 in. square.
1 set 6⅝ in. nom. all steel bits, 3¼ in. × 4¼ in. 7 flat I. & H. 4 in. square.
1 set 350 lbs. tool wrenches, 5 in. bushed to 4 in.
1 each 13 in., 10 in., 8½ in., 6⅝ in. tool gauge.
2 New Era rope sockets, 2¾ in. × 3¾ in. 7 flat I. & H. 4 in. sq.
1 set 5½ in. drilling jars, 2¾ in. × 3¾ in. 7 flat I. & H. 4 in. sq.
1 ball-bearing derrick crane complete.
1 No. 2 Barrett jack with wrench rack.
1 5½ in. × 25 ft. W.I. bailer.
1 7 in. × 25 ft. „ „
1 9 in. × 19 ft. „ „
1 spare bail and valve for each size bailer.
1 Morahan sand pump for each size pipe.
1 Conductor bailer 10 ft. long.
1 1¾ in. × 5 ft. 10 in. ball bearing temper screw complete.
1 box and pin for each size.
1 spudding shoe ("O.K.").

Tools for Handling Pipe and Casing.

2 4½ in. double sheave hooks.
1 28 in. all iron casing block, single.
1 28 in. „ „ „ double.
1 set 6⅝ in. W.I. elevators Mannington pattern.
1 set 8¼ in. „ „ „ „
1 set 10 in. „ „ „ „
1 chain tong (No. 15 Vulcan).
1 set casing wagons.
1 pr. 2 in. tongs (Crumbie).
1 pr. 2½ in. „ „
1 18 in. wrench (Trimo).
1 15 in. combination wrench.
1 10 in. "S" wrench.
1 ring and wedges for 13 in. and 10 in. pipe.
1 „ „ „ 8¼ in. and 6⅝ in. casing.
1 set driving clamps, 4½ in. × 4½ in. × 14 in. iron with 2½ in. bolts for clamping on 4 in. square of drill stem.
1 pr. drive clamp wrenches.

Fishing Tools.

1 set 5½ in. fishing jars.
1 horn socket for 6⅝ in. hole, 2¾ in. × 3¾ in. 7 I. & H. 4 in. sq.
1 combination socket for 6⅝ in. hole, 2¾ in. × 3¾ in. 7 I. & H. 4 in. square.
1 slip socket for 8¼ in. hole, 2¾ in. × 3¾ in. 7 I. & H. 4 in. sq.
1 latch jack for 6⅝ in. hole, 2¾ in. × 3¾ in. 7 I. & H. 4 in. sq.
1 trip rope knife. 1 rope knife sinker. 1 rope knife jar.
1 rope spear for 6⅝ in. hole, 2¾ in. × 3¾ in. 7 I. & H. 4 in. sq.
1 rope grab for do.

Blacksmith's Tools and Miscellaneous.

1 steam blower.
1 200 lb. anvil.
2 14 lb. sledges with handles.
1 ball peen hammer.
1 pr. blacksmith's tongs.
1 combination pipe vice.
1 ratchet stock and dies.
1 malleable stock and dies.
1 pipe cutter.
2 sets 12 in. extra heavy belt clamps.
1 grooved wheel.
1 telegraph cord.
Carpenter's tools for rig building.
6 5 in. hay fork pulleys.
1 2,000 ft. measuring line and reel.

N.B.—Casing heads and oil savers should be specified for a prospecting outfit as extras. Every specification of drive pipe and casing should include suitable drive heads and drive shoes.

Specification No. 2.

AMERICAN-CALIFORNIAN RIG FOR 4,000 FT.

As the title indicates, this specification represents the American cable method used in California, where the calf wheel was first introduced, in order to handle long strings of casing without disturbing the drilling cable. California type of casing should be used with this system, as drive pipe and ordinary casing will not withstand the strain of surging or working in long strings in soft formations. This rig is largely adopted in foreign fields, particularly for pioneer work. It is not uncommon in California for the rig irons to be increased to 7½ in. for the greater depths, but the extra size shaft and larger dimensions throughout are not considered essential by some engineers. Where geological conditions are difficult and the maximum depth desired, 7½ in. rig irons should be specified.

Derrick.

86 ft. × 24 ft. base. Usually all steel or tubular derricks are used, except where good timber is obtainable. 6-pulley crown block.

NOTE.—If rotary as auxiliary is anticipated, it is desirable to specify 106 ft. derrick.

Rig Irons.

1 6 in. × 7 ft. 6 in. shaft.
1 crank.
1 set 36 in. flanges and bolts.
1 wrist pin.
2 6 in. shaft collars.
5 flange and crank keys.
1 7 ft. sprocket tug rim.
1 42 in. clutch sprocket wheel.
1 6 in. plain clutch.
1 clutch strap and 1 clutch lever.
2 clutch keys.
1 6 in. × 14 in. jack post box and cap.
1 6 in. × 12 in. calf wheel box and cap.
4 1½ in. × 8 ft. 6 in. turnbuckle rods.
2 1½ in. × 8 ft. 4 in. jack post rods.
1 2 in. × 6 in. × 22 in. jack post plate.
2 1½ in. × 48 in. eye bolts.
1 1½ in. × 26 in. double end bolt.
1 ⅞ in. × 8 ft. 6 in. „ „ „
2 ⅞ in. × 10 ft. 4 in. „ „ „
1 set centre irons and bolts.
1 set 16 in. bull wheel gudgeons, bands and bolts.
1 16 in. calf wheel gudgeon, bands and bolts.
1 30 in. „ „ „ „ „

1 ½ in. × 7 in. × 28 ft. brake band, lever and staple.
1 $\frac{5}{16}$ in. × 6 in. × 28 ft. brake band, lever and staple.
1 2½ in. round iron stirrup.
1 24 in. sand line sheave.
1 36 in. crown pulley.
4 22 in. casing line pulleys.
55 ft. sprocket chain.
1 set cants, arms and handles for 8 ft. bull wheel.
1 „ „ for 10 ft. band wheel.
1 „ „ arms and handles for 7½ ft. calf wheel.
1 complete set bolts, nails, washers and guy wire.
1 sand reel, 42 in. × 13 in. web pulley, 4 in. × 9 ft. shaft.
2 12 in. × 18 in. web drums, 40 in. steel flanges with lever and reach strap.

Machinery.

1 steam boiler capable of evaporating with ease 2,500 lbs. of water per hour at 100 lbs. steam pressure with fuel found in the district, fitted with injector and spares.
1 horizontal 12 in. × 12 in. single cylinder reversing steam engine, with pulley and flywheel, feed pump and feed water heater, with means for operating both throttle valve and reversing gear from the derrick, and spares and belting.

Cordage and Belting.

1 2½ in. × 1,500 ft. Manila drilling cable.
3 2½ in. × 95 ft. bull ropes.
1 $\frac{7}{8}$ in. × 6,000 ft. 6 × 19 wire drilling line.
1 ½ in. × 3,000 ft. 6 × 7 wire sand line.
1 1 in. × 1,100 ft. wire casing or tubing line.
1 1¼ in. × 40 ft. endless wire dead line (92 ft.).
200 ft. 1¼ in. plain laid rope.
200 ft. 1 in. „ „ „
200 ft. $\frac{7}{8}$ in. „ „ „
1 12 in. 6-ply × 95 ft. rubber belt.
6 sets 12 in. extra heavy belt clamps and 24 extra bolts for same.
6 each ½ in., $\frac{7}{8}$ in., 1 in. wire rope clips.

Drilling Tools.

1 5½ in. × 38 ft. stem, pin 2¾ in. × 3¾ in. 7, box 3½ in. × 4½ in. 7.
1 4½ in. × 40 ft. „ „ „ „ 2¾ in. × 3¾ in. 7.
1 4½ in. × 32 ft. „ „ „ „ „ „
1 4½ in. × 16 ft. „ „ „ „ „ „
3 sets 5½ in. diameter drilling jars, 2¾ in. × 3¾ in. 7.
3 2¾ in. × 3¾ in. rope sockets for 2½ in. cable.

1 15½ in. all steel bit 5 ft. 6 in. long, 3½ in. × 4½ in. pin.
1 12½ in. „ „ „ 6 ft. „ „ „
1 set 8½ in. all steel bit 6 ft. „ 2¾ in. × 3¾ in. pin.
1 „ 6¼ in. „ „ „ 6 ft. „ „ „
1 15½ in. „ „ „ 5 ft. 6 in. „ 3½ in. × 4½ in. pin.
1 12½ in. „ „ „ 6 ft. „ „ „
1 set 10 in. „ „ „ 6 ft. „ „ „
1 set 8½ in. „ „ „ 6 ft. „ „ „
2 2¾ in. × 3¾ in. 7, boxes for welding.
1 3½ in. × 4½ in. 7, „ „
2 2¾ in. × 3¾ in. 7, pin 3½ in. × 4½ in. 7, box subs.
1 11 in. × 19 ft. W.I. bailer for 14 in. O.D. hole.
1 9 in. × 19 ft. „ „ 10 in. „
1 7 in. × 25 ft. „ „ 8¼ „ „
1 5 in. × 25 ft. „ „ 6¼ „ „
1 bailer dump for 2 in. pipe.
1 2 in. × 5 ft. 10 in. temper screw with Manila rope lower parts and inserted boxes.
1 ⅞ in. wire line clamps with 1 set extra slips.
1 2¾ in. × 3¾ in. rope socket for ⅞ in. wire line.
1 set tool wrenches, 5 in. square.
1 „ „ „ 4 in. „
1 9⅝ in. sand pump.
1 12½ in. underreamer, 2¾ in. × 3¾ in. 7, 4 in. square.
1 10 in. „ „ „ „ „
1 8¼ in. „ „ „ „ „
1 6¼ in. „ „ „ „ „
1 extra set cutters for 12½ in., 10 in., 8¼ in., 6¼ in. underreamer.
1 ball-bearing derrick crane complete with hoist and swivel wrench.
1 No. 2 Barrett jack with wrench rack.

Tools for Handling Pipe and Casing.

1 set 12½ in. Mannington pattern elevators.
1 „ 10 in. „ „ „
1 „ 8¼ in. „ „ „
1 „ 6¼ in. „ „ „ with 2¼ in. links.
1 „ California pattern chain tongs with removable jaws for 15½ in., 12½ in., 10 in., 8¼ in. and 6¼ in. casing.
1 set California pattern back-up tongs.
1 pipe grip.
3 chain tongs. Nos. 15, 14 and 13 Vulcan.
1 pr. each 2 in. and 2½ in. tongs with 24 bits for same.

1 pr. each 2 in. and 2½ in. tongs.
1 6½ in. double swivel casing hook.
1 5½ in. „ „ „
1 34 in. quadruple bronze bushed steel block with 4 in. centre pin.
1 each 10 in., 8 in., 7 in. steel pulley blocks.
1 set casing wagons (front and back).
1 bail for 15½ in. O.D. 10-thread California casing, riveted to pipe, 2 in. steel pin through box and pin.
1 set 5 in. × 5 in. × 24 in. California pattern drive clamps with bolts 2¼ in. × 17 in.
1 wrench for above.
2 extra bolts for drive clamps.
1 each 15½ in., 12½ in., 10 in., 8¼ in., 6¼ in. cast steel drive heads.
1 10 in. California pattern drive shoe, 1⅛ in. × 16 in. long.
1 8¼ in. „ „ „ „ 1 in. × 16 in. „
1 6¼ in. „ „ „ „ 1 in. × 12 in. „
2 200 ton hydraulic jacks, double piston single outside pump.
1 combination pipe vice. 1 screw plate.
1 malleable pipe vice. 2 pipe cutters.
1 stock and dies. 6 wheels for above.
1 malleable stock with solid dies.

Fishing Tools.

1 10 in. fluted swedge, 2¾ in. × 3¾ in. 7, pin.
1 8¼ in. „ „ „ „ „
1 6¼ in. „ „ „ „ „
1 10 in. casing spear, 2¾ in. × 3¾ in. 7, pin.
1 8¼ in. „ „ „ „ „
1 6¼ in. „ „ „ „ „
1 15½ in. ring with wedges for pulling 15½ in., 10 in., 8¼ in., and 6¼ in. pipe.
1 set 5½ in. × 36 in. stroke fishing jars, 2¾ in. × 3¾ in. 7.
1 combination socket for 6¼ in. hole „ „
1 slip socket for 10 in. hole, 2¾ in. × 3¾ in. 7, with bowl for 12½ in. hole.
1 slip socket for 6¼ in. hole, 2¾ in. × 3¾ in. 7, with bowl for 8¼ in. hole.
1 collar socket for 6¼ in. hole, 2¾ in. × 3¾ in. 7.
1 forged steel friction socket for 6¼ in. hole, 2¾ in. × 3¾ in. 7.
1 side jar socket for 6¼ in. hole, to catch 5½ in. diameter jars.
1 horn socket for 8¼ in. hole with bowl.
1 boot jack for 6¼ in. hole.

1 centre rope spear for 6¼ in. hole.
1 3-wing rope grab for 6¼ in. hole.
1 8 in. bit hook, 10 ft. long.
1 horse shoe trip rope knife complete with jars and sinker.
1 ⅞ in. wire rope knife complete with jars and sinker.
1 jar bumper, 16 ft. long.
2 100-ton hydraulic jacks, double piston single outside pump.

Blacksmith's Tools.

1 200 lb. anvil.
1 B.P. hammer.
1 C.P. sledge and handle.
1 14 lb. and 1–12 lb. S.P. sledge and handles.
6 splitting chisels.
1 ⅝ in. bottom swedge.
6 1¼ in. cold chisels.
1 diamond point chisel.
1 ¾ in. caulking chisel.
1 hot chisel, large handle hole.
1 hardy.
1 3 in. flatter.
1 cold chisel.
1 set hammer.
2 steel punches.
1 ⅝ in. top fuller.
2 crow bars.
1 „ bottom fuller.
1 toolies kit.
1 „ top swedge.
1 ½ in. sand line cap for 8¼ in. casing head.
1 each 12½ in. × 10 in., 10 in. × 8¼ in., and 8¼ in. × 6¼ in. stuffing box casing heads.
1 6¼ in. 4-way casing head.
1 each 12 in. × 15 in. combination wrenches.
1 24 in. wrench.
1 14 in. wrench.
1 6¼ in. × 2¾ in. patent barrel oil saver.
2 socket peavies.
2 2 in. × 20 in. lift jack screws and 2 1½ in. × 12 in. lift jack screws.
2 square point D handle shovels.
2 round point long handle shovels.
2 picks.
2 mattocks.
6 pick and mattock handles.
Carpenter's tools for rig building.
12 12 in. strap hinges.
12 12 in. hinge hasps and staples.
4 1 in. turnbuckles.
4 bars each ⅝ in., ¾ in., ⅞ in. and 1 in. round iron.
10 ft. 1 in. hexagon tool steel.
½ barrel engine oil.
½ barrel cylinder oil.
5 gallons lard oil.
1 5-gallon oil can.

5 lbs. $\frac{3}{4}$ in. asbestos piston packing.
1 yd. $\frac{1}{4}$ in. packing.
1 „ $\frac{5}{16}$ in. „
1 sheet 40 in. × 40 in. × $\frac{5}{16}$ in. asbestos mill board.
20 ft. 1 in. 4-ply steam hose and couplings.
40 ft. 1 in. 3-ply water hose and couplings.

100 lbs.	Babbitt metal.	1	auger handle.
1	6 in. long melting ladle.	24	5 in. rig pulleys, 3 grooved derrick wheels.
1	box dry graphite.		
6	12 in. $\frac{1}{2}$ round bastard files.	3	150 ft. wire telegraph cords.
6	10 in. flat bastard files.		
2	12 in. square „ „	1	belt punch.
2	10 in. round „ „	1	steam blower.
6	5 in. slim taper saw files.	1	injector.
6	6 in. „ „ „ „	1	1 in. steam jet.
1	large expansive bit with 2 cutters.	1	spudding shoe and ring.
		1	derrick stove.
3	hatchets.	1	36 in. grindstone complete with fixtures.
6	„ handles.		
1	D.B. axe with handles.	1	steel wheelbarrow.
1	S.B. „ „ „	1	adze eye nail hammer.
12	sledge handles.	1	ratchet.

Fittings.

8	2 in. iron cocks.
24	2 in., 48–1 in., 12–$\frac{1}{2}$ in., 12–$\frac{3}{4}$ in. malleable tees.
24	2 in., 48–1 in., 12–$\frac{1}{2}$ in., 12–$\frac{3}{4}$ in. „ ells.
24	2 in., 48–1 in., 12–$\frac{1}{2}$ in., 12–$\frac{3}{4}$ in. C.I. plugs.
36	1 in. globe valves with 48–1 in. seats for same.
24	1 in. malleable iron lip unions.
24	2 in. × 1 in., 12–1 in. × $\frac{1}{2}$ in., 12–$\frac{1}{2}$ in. × $\frac{3}{4}$ in., 12–$\frac{3}{4}$ in. × $\frac{1}{4}$ in. bushings.
12	2 in. flange unions.
12	$\frac{3}{4}$ in. and 12–$\frac{1}{2}$ in. standard globe valves.
48	2 in., 72–1 in., 12–$\frac{1}{2}$ in., and 12–$\frac{3}{4}$ in. assorted nipples.
1	15$\frac{1}{2}$ in. × 10 in., 1–10 in. × 8$\frac{1}{2}$ in., 1–8$\frac{1}{2}$ in. × 6$\frac{1}{2}$ in. and 1–6$\frac{1}{2}$ in. × 2 in. swedged nipples.

N.B.—Casing heads and oil savers should be specified for a prospecting outfit as extras. Every specification of drive pipe and casing should include suitable drive heads and drive shoes.

Specification No. 3.

CANADIAN STANDARD RIG FOR 2,000 FT.

It is claimed that there are advantages in the use of the pole tool system, known as Canadian, for drilling in soft formations, whereby the rotating of poles prevents "flat" or crooked holes. The drilling staff is larger, although not necessarily so highly skilled as for the more rapid systems. The pole system has been extensively adopted in Europe, and in certain parts of the world. The following specification is for tools and supplies for standard coupled casing, although it is adaptable for, and customarily used for, inserted joint casing.

Derrick.

A standard tubular or steel derrick should be provided, not less than 60 ft. in height with 18 ft. base; otherwise a specification for timber and lumber should be added.

Rig Irons.

Assuming timber is available for both derrick and rig, the following *rig irons* are required:—

1 5 in. × 7 ft. counter shaft.
1 steel crank.
1 3 in. diameter wrist pin.
1 set wrist pin collars and set screws.
1 set wood bearings, babbitted for shaft, 5 in. diameter.
4 1¼ in. × 4 ft. 5 in. bolts for shaft boxings.
2 1¼ in. × 3 ft. 1 in. „ „ „
2 1½ in. × 3 ft. 1 in. „ „ „
1 steel drive wheel, 4 ft. diameter, 15 in. face.
1 „ „ „ 4 ft. „ 11 in. „
1 „ „ „ 6½ ft. „ 15 in. „
1 steel draw spool.
1 steel sand pump spool.
1 pair C.I. boxings, babbitted for sand line spool.
1 pair C.I. boxings, babbitted for draw spool.
2 spool chains, each 5 ft. long, ½ in. diameter, with swivels and clevises.
1 brake band 10 ft. 4 in. long, 4 in. wide, ¼ in. thick.
1 brake band 12 ft. 4 in. long, 6 in. wide, ¼ in. thick.
2 iron belt tighteners complete with frames.
2 sets draw irons.
1 walking beam saddle, 3½ in. shaft.
1 iron plate for saddle.
1 pair boxings, babbitted for saddle.

1 top pitman iron and bolt, heavy.
1 boxing for top pitman.
1 bottom pitman, iron, solid forged with bolts and brasses for 3 in. wrist pin.
1 slipper-out, extra heavy, with steel wheel and double dog.
1 spring pole complete with C.I. jacket.
1 stirrup bolt with plates for spring pole.
1 King bolt for spring pole.
2 22 in. casing line pulleys.
1 36 in. derrick pulley.
1 24 in. sand-line pulley.
1 drill chain, 30 ft. long, 10 ft. $\frac{5}{8}$ in., 20 ft. $\frac{7}{8}$ in., with swivels and clevises.
1 wrench block, heavy, with iron top and bottom.
1 rope weight, heavy, with swivels and clevises.
1 sand pump hanger.
1 rope weight.
1 set cants, arms and handles for 7½ ft. single tug, left hand bull wheels, 9 in. brake irons.
1 ¼ in. × 9 in. × 28 ft. brake band and staple.
1 1¾ in. × 9 ft. brake lever.

Machinery.

1 steam boiler capable of evaporating with ease 1,500 lbs. of water per hour at 100 lbs. steam pressure with fuel found in the district, fitted with injector and spares.
1 horizontal 11½ in. × 12 in. single cylinder reversing steam engine, with pulley and flywheel, feed pump and feed water heater, with means for operating both throttle valve and reversing gear from the derrick, and ample spares and belting.

Wire Ropes.

1 $\frac{7}{8}$ in. draw line, 120 ft. long, 6 × 19 construction, fitted with two thimbles.
1 $\frac{5}{8}$ in. casing line, 650 ft. long, 6 × 19 construction, fitted with one thimble.
2 $\frac{9}{16}$ in. sand lines, 2,500 ft. long, 6 × 12 construction, fitted with two thimbles.
2 $\frac{7}{8}$ in. drilling cables, 2,500 ft. long, 6 × 19 construction fitted with one thimble.

Drill Poles.

84 special iron drill poles, each 36 ft. long × 1 in. dia. = 3,024 ft. small pole joint.

8 tubular hand poles, 2 each 5 ft., 6 ft., 10 ft., and 15 ft., for each size joint.
20 pairs small pole joints for welding.

Drilling Bits.

2 15″ spudding bits, 3″×4″ pin, wt. 420 lbs. each.
3 drilling bits to work inside 12⅜″ I.D. drive pipe, 3″×4″ joint, 4½″ sq., wt. 420 lbs.
3 do., 10″ pipe, 3″×4″ joint, 4½″ sq., wt. 375 lbs.
3 do., 8″ pipe, 2½″×3½″ joint, 4″ sq., wt. 320 lbs.
3 do., 6½″ pipe, 2½″×3½″ joint, 4″ sq., wt. 270 lbs.
3 do., 5″ pipe, 1¾″×2¾″ joint, 3″ sq., wt. 180 lbs.
3 eccentric bits to work inside 12⅜″ pipe, O.D. of shoe 14½″, 3″×4″ joint, 4½″ sq., wt. 450 lbs.
3 do., 10″ pipe, O.D. of shoe 12″, 3″×4″ joint, 4½″ sq., wt. 400 lbs.
3 do., 8″ pipe, O.D. of shoe 9½″, 2½″×3½″ joint, 4″ sq., wt. 300 lbs.
3 do., 6½″ pipe, O.D. of shoe 7$\frac{13}{16}$″, 2½″×3½″ joint, 4″ sq., wt. 250 lbs.
3 do., 5″ pipe, O.D. of shoe 6$\frac{3}{16}$″, 1¾″×2¾″ joint, 3″ sq., wt. 150 lbs.
1 5 in. sinker, 25 ft. long, 3 in. × 4 in. joint, 4½ in. square.
1 5 in. „ 15 ft. „ 3 in. × 4 in. „ 4½ in. „
1 4½ in. „ 25 ft. „ 2½ in. × 3½ in. „ 4 in. „
1 3½ in. „ 25 ft. „ 1¾ in. × 2¾ in. „ 3 in. „
1 3 in. „ 20 ft. „ large pole joints for sand pump and fishing.
1 6½ in. drilling jar, 3 in. × 4 in. joint, 4½ in. squares.
1 5⅛ in. „ „ 2½ in. × 3½ in. „ 4 in. „
1 4⅛ in. „ „ 1¾ in. × 2¾ in. „ 3 in. „
1 5⅛ in. fishing „ 2½ in. × 3½ in. „ 4 in. „
1 4⅛ in. „ „ 1¾ in. × 2¾ in. „ 3 in. „
1 substitute 3 in. × 4 in. box, 2½ in. × 3½ in. pin.
1 „ 3 in. × 4 in. pin, 2½ in. × 3½ in. box.
1 „ 3 in. × 4 in. box, large pole pin.
1 „ 2½ in. × 3½ in. box, 1¾ in. × 2¾ in. pin.
1 „ 2½ in. × 3½ in. pin, 1¾ in. × 2¾ in. box.
1 „ 2½ in. × 3½ in. box, large pole pin.
1 „ 1¾ in. × 2¾ in. „ „ „ „
1 „ 1¾ in. × 2¾ in. pin, large pole box.
1 „ large pole pin, small pole box.
1 „ large pole box, small pole pin.

2 heavy tool wrenches for 4½ in. squares.
2 „ „ „ „ 4 in. „
2 „ „ „ „ 3 in. „
2 knock wrenches.
1 catch wrench.
2 chain levers (1 heavy and 1 light).
1 key wrench for iron poles.
2 pole swivels with chain for 1 in. poles.
2 sand pump swivels.
1 pole hook.
1 sand pump hanger and chain.
1 12 in. mud pump, 6 ft. long, with hinged bail and large pole pins.
2 10¾ in. sand pumps, 18 ft. long, with large pole pin.
2 8⅝ in. „ 18 ft. „ „ „ „ „
2 7 in. „ 18 ft. „ „ small „ „
2 5½ in. „ 36 ft. „ „ „ „ „
2 4⅞ in. „ 36 ft. „ „ „ „ „
1 spare valve for each of above.
1 patent wire rope swivel 3 in. × 4 in. box.
1 „ „ „ „ 2½ in. × 3½ in. „
1 „ „ „ „ 1¾ in. × 2¾ in. „
1 heavy wire rope drilling clamp.

Tools for Handling Pipe and Casing.

1 pair Mannington elevators for 13 in. O.D. drive pipe.
1 „ „ „ 10¾ in. „ „
1 „ „ „ 8⅝ in. „ „
1 „ „ „ 7 in. „ „
1 „ „ „ 5½ in. „ „
1 extra heavy quadruple block with 15 in. sheaves and shackle bronze-bushed throughout.
1 extra heavy treble block with 15 in. sheaves and swivel head bronze-bushed throughout.
2 light blocks for 1¼ in. rope.
1 steel plate suitable for 13 in. and 10¾ in. O.D. drive pipe.
1 set of wedges for 13 in. O.D. drive pipe.
1 „ „ 10¾ in. „ „ „
1 steel plate suitable for 8⅝ in. and 7 in. O.D. drive pipe.
1 set of wedges for 8⅝ in. O.D. drive pipe.
1 „ „ 7 in. „ „ „
1 steel plate suitable for 5½ in. O.D. drive pipe.
1 set of wedges for 5½ in. O.D. drive pipe.

Heavy Pattern.

Fishing Tools.

1 slip socket for recovering 1 in. iron pole, in 8 in. I.D. drive pipe, with bonnets for 10 in. and 12⅜ in., 2½ in. × 3½ in. joint.
1 slip socket for recovering 1 in. iron poles in 5 in. I.D. drive pipe, with bonnets for 6½ in. and 1¾ in. × 2¾ in. joint.
2 spare sets slips for each size.
1 hook with dog for 10 in. hole, 2½ in. × 3½ in. joint.
1 „ „ „ 6½ in. „ 1¾ in. × 2¾ in. „
1 horn socket, 12⅜ in. hole, 2½ in. × 3½ in. joint.
1 „ „ 8 in. „ 2½ in. × 3½ in. „
1 „ „ 6½ in. „ 1¾ in. × 2¾ in. „
1 „ „ 5 in. „ 1¾ in. × 2¾ in. „
1 wire rope knife, large pole pin joint.
1 „ „ „ sinker joint.
1 „ „ „ jar „
1 „ „ „ hook „
1 wire rope spear, 1¾ in. × 2¾ in. joint.
1 „ „ grab 1¾ in. × 2¾ in. „
1 spud 10 ft. long for 10 in. hole, 3 in. × 4 in. joint.
1 „ „ 6½ in. „ 2½ in. × 3½ in. „
2 60-ton hydraulic jacks.
2 pairs 3 in. × 4 in. joints for welding.
2 „ 2½ in. × 3½ in. „ „
2 „ 1¾ in. × 2¾ in. „ „
3 pole joints for welding.
1 swedge fluted for working inside 10 in. I.D. drive pipe.
1 „ „ „ 8 in. „ „
1 „ „ „ 6½ in. „ „
1 „ „ „ 5 in. „ „
1 pair drive clamps and bolts to fit 4½ in. squares.
1 „ „ „ 4 in. „
1 „ „ „ 3 in. „
1 set spanners.

N.B.—Casing heads and oil savers should be specified for a prospecting outfit as extras. Every specification of drive pipe and casing should include suitable drive heads and drive shoes.

Specification No. 4.

CANADIAN-GALICIAN RIG FOR 4,000 FT.

The following is a typical specification in use in the Galician oilfields at the outbreak of war, and the authors are much indebted to Mr. Albert Millar, who has had many years experience in Galicia,

for his kind assistance in its drafting. The derrick is usually constructed of local timber, and this item, therefore, is only represented by the requisite ironwork. It is possible that steel or tubular derricks may be introduced into Galicia at a later date.

The pipe used in Galicia is of the inserted joint (Austrian standard) type.

Rig. (*Ironwork.*)

1 countershaft steel 8 ft. 6 in. long, dia. 6 in.
1 crank cast steel with $\frac{3}{4}$ in. borings for wrist pin 3 in. dia.
1 wrist pin, wrought steel $\frac{3}{4}$ in. dia. with key.
2 oak boxings for countershaft (babbitted). (Alternative C.I. boxes.)
2 wrought iron plates for countershaft oak boxings $\frac{7}{8}$ in. thick. $1\frac{1}{4}$ in. bolts and nuts for countershaft boxings. (Usually made locally.)
2 cast iron oil cups for countershaft boxings.
1 cast iron set collar with set screw.
1 wrought iron band wheel 6 ft. dia. 16 in. wide with cast iron hub.
1 wrought iron key for above.
2 wrought iron band wheels in two parts 4 ft. in dia. 16 in. wide with cast iron hubs.
2 wrought iron keys for above.
1 wrought iron draw spool with brake ring, 3 ft. 4 in. dia. 5 in. wide, drum 12 in. dia., pulley 3 ft. 6 in., shaft ends $2\frac{5}{8}$ in. dia.
1 sand line spool 8 ft. 6 in. between boxings, drum 1 ft. 4 in. dia., pulley 3 ft. 6 in. dia., brake ring 3 ft. 4 in. dia. 5 in. wide, shaft ends $2\frac{5}{8}$ in. dia.
2 steel brake bands with brass or copper blocks for the above last two items.
2 cast iron solid boxings (babbitted) for drawspool with ring lubricators.
1 brake shaft for sand line spool.
1 brake shaft complete with levers.
2 wrought iron belt tighteners (jockey-pulleys) with frames.
4 cast iron boxings for belt tightener shafts.
2 belt tightener shafts 8 ft. long 2 in. dia., with C.I. set collars.
2 draw irons for belt tighteners with levers.
1 cast iron sand line pulley 3 ft. 4 in. dia. for 19 mm. dia. wire rope, 3 in. shaft.
2 C.I. solid boxings (babbitted) with ring lubricators for sand line pulley.

2 H girders for sand line pulley in derrick crown 8 ft. long 9 in. deep.
4 stirrup irons for above boxings.
3 H girders mild steel 8 ft. long, 9 in. deep, with distance pieces and bolts.
2 C.I. rope pulleys 22 in. dia. with 3 in. shafts.
1 snatch pulley 12 in. dia.
2 C.I. boxings for above.
2 C.I. double solid boxings (babbitted) for crown pulleys ring lubricated.
4 stirrup irons for above.
1 chain jacket with double central guide.
2 sets stirrup bolts with plates for fixing chain jacket to walking beam.
1 walking beam shaft 5 in. dia. with 4 in. journals.
1 wrought iron walking beam bed plate.
2 C.I. boxings with oil cups for w.b. shaft.
1 slipperout with worm adjustment and chain wheel.
1 complete pitman shaft with brasses adjustable by means of cotter and nut and fitted with lubricator or pressure grease cup.
1 drill chain 30 ft. long of 1 in. chain and clevis.
1 oak boxing (babbitted) for pitman shaft.
1 wrench block and drill pole stand in two parts (wood) sheet iron covered. (N.B.—In use only during early part of boring.)
1 wrench block (all iron) with sides, copper plate, and fitted with flanges for oil and gas.
1 rope weight with 2 ft. 6 in. of 1 in. chain and clevices complete.

Boiler and Drilling Engine.

1 Austrian type portable boiler with circular corrugated furnace having 50 sq. metres heating surface to work at 10 atmospheres pressure. This boiler will evaporate 2,000 lbs. of water per hour.
1 chimney 12 metres long fitted with spark catcher.
2 injectors.
1 oil burner.
1 gas burner.
1 fuel tank on stand for 2 tons of oil and fitted with heating coil.
1 hand wing pump for oil fuel tank.
1 steam drilling engine developing 45 h.p. at 120 revs. p.m. at 6 atmospheres, fitted with flywheel, driving pulley 30 in. dia., 16 in. wide. Throttle valve and lubricators.

Wire Ropes.

1 sand line 19 mm. dia. construction 6 strands of 19 wires with 1 eye.

1 draw line 25 mm. dia. 56 metres long, construction 6 strands of 24 wires.

1 casing line 28 mm. dia. 250 metres long, construction 6 strands of 37 wires with 2 thimbles.

Belts.

Camel hair belting 14 in. wide (approximately 50 metres total length).

Belt fasteners.

Drilling Poles. (Wrought Iron—Lowmoor.)

		Threads per in.
30	poles 30 mm. dia., 11 mtrs. long, diam. of pin : 35 mm. top, 46 mm. bottom	6
2	poles 30 mm. dia., 1½ mtrs. long, diam. of pin : 35 mm. top, 46 mm. bottom	6
2	poles 30 mm. diam., 2 mtrs. long, diam. of pin : 35 mm. top, 46 mm. bottom	6
2	poles 30 mm. diam., 3 mtrs. long, diam. of pin : 35 mm. top, 46 mm. bottom	6
2	poles 30 mm. diam., 4½ mtrs. long, diam. of pin : 35 mm. top, 46 mm. bottom	6
20	pairs spare pole joints.	
60	poles 25 mm. diam., 11 mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 25 mm. diam., 1½ mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 25 mm. diam., 2 mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 25 mm. diam., 3 mtrs. long, 26 mm. top, 37 mm. bottom	
2	poles 25 mm. diam., 4½ mtrs. long, 26 mm. top, 37 mm. bottom	6
20	pairs spare pole joints.	
120	poles 22 mm. diam., 11 mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 22 mm. diam., 1½ mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 22 mm. diam., 2 mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 22 mm. diam., 3 mtrs. long, 26 mm. top, 37 mm. bottom	6
2	poles 22 mm. diam., 4½ mtrs. long, 26 mm. top, 37 mm. bottom	6
30	pairs spare pole joints.	

Winged Drilling Bits. (Spudding Bits.) Casing diam.

2 breadth of cutting edge, 380 mm.; diam. of collar, 180 mm.; height of pin, 127·5 mm.; diam. of pin: top 115, bottom, 132; threads per inch, 6; wrench sq., 140 mm. ... ...16 in.

2 breadth of cutting edge, 343 mm.; diam. of collar, 160 mm.; height of pin, 120 mm.; diam. of pin: top, 100, bottom, 116; threads per inch, 6; wrench sq., 120 mm. ... ...14 in.

2 breadth of cutting edge, 285 mm.; diam. of collar, 160 mm.; height of pin, 120 mm.; diam. of pin: top 100, 116 bottom; threads per inch, 6; wrench sq., 120 mm. 12 in.

Eccentric Bits.

2 breadth of cutting edge, 285 mm.; diam. of collar, 160 mm.; height of pin, 120 mm.; diam. of pin: 100 top, 116 bottom; threads per inch, 6; wrench sq., 120 mm. ... ...12 in.

2 breadth of cutting edge, 245 mm.; diam. of collar, 160 mm.; height of pin, 120 mm.; diam. of pin: 100 top, 116 bottom; threads per inch, 6; wrench sq., 120 mm. ... ...10 in.

2 breadth of cutting edge, 215 mm.; diam. of collar, 150 mm.; height of pin, 105 mm.; diam. of pin: top, 85 100 bottom; threads per inch, 6; wrench sq. 110 mm. 9 in.

2 breadth of cutting edge, 175 mm.; diam. of collar, 125 mm.; height of pin, 100 mm.; diam. of pin: 64 top, 84 bottom; threads per inch, 7; wrench sq. 100 mm. 7 in.

2 breadth of cutting edge, 146 mm.; diam. of collar, 102 mm.; height of pin, 80 mm.; diam. of pin: 49 top, 66 bottom; threads per inch, 7; wrench sq., 80 mm. 6 in.

Sinkers.

1 diam., 180 mm.; length, 3,000 mm.; collar, 180 mm.; diam. of pin: 115 mm. top, 132 mm. bottom; approx. weight, 645 kg. } special short sinker for spudding 16 in.

1 diam., 180 mm.; length, 6,000 mm.; collar, 180 mm.; diam. of pin: 115 mm. top, 132 mm. bottom; approx. weight, 1,290 kg.

2 diam. 155 mm.; length, 6,000 mm.; collar, 160 mm.; diam. of pin: 100 mm. top, 116 bottom; approx. weight, 900 kg. ... 14 in. and 12 in.

1 diam., 130 mm.; length, 7,500 mm.; collar, 150 mm.; diam. of pin: 85 mm. top, 100 mm. bottom; approx. weight, 890 kg. 10 in.

		Casing diam.
1	diam., 120 mm.; length, 7,500 mm.; collar, 125 mm.; diam. of pin: 64 mm. top, 84 mm. bottom; approx. weight, 775 kg.	9 in.
1	diam., 105 mm.; length, 7,500 mm.; collar, 102 mm.; diam. of pin: 49 mm. top, 66 mm. bottom; approx. weight, 510 kg.	7 in.
1	diam., 95 mm.; length, 7,500 mm.; collar, 90 mm.; diam. of pin; 45 mm. top, 60 mm. bottom; approx. weight, 420 kg. ...	6 in.
1	diam., 60 mm.; length, 7,000 mm.; collar, 60 mm.; diam. of pin: 35 mm. top, 46 mm. bottom; approx. weight, 160 kg.	sand pumping & light fishing.

Jars.

		Approx. Weight.
2	diam. of body, 175 mm.; stroke, 180 mm.; collar, 180 mm.; diam. of pin: 115 mm. top, 132 mm. bottom	250 kg.
2	diam. of body, 175 mm.; stroke, 180 mm.; collar, 160 mm.; diam. of pin: 100 mm. top, 116 mm. bottom	250 kg.
2	diam. of body, 175 mm.; stroke, 180 mm.; collar, 150 mm.; diam. of pin: 85 mm. top, 100 mm. bottom	240 kg.
2	diam. of body, 140 mm.; stroke, 180 mm.; collar, 125 mm.; diam. of pin: 64 mm. top, 84 mm. bottom	175 kg.
2	diam. of body, 124 mm.; stroke, 180 mm.; collar, 102 mm.; diam. of pin: 49 mm. top, 66 mm. bottom	140 kg.
2	diam. of body, 102 mm.; stroke, 180 mm.; collar, 90 mm.; diam. of pin: 45 mm. top, 60 mm. bottom	95 kg.
1	diam. of body, 70 mm.; stroke, 175 mm.; collar, 60 mm.; diam. of pin: 35 mm. top, 46 mm. bottom	65 kg.

Substitutes.

1 complete set for inter-connecting all joints. (N.B.—Those for use with collars 180 mm., 160 and 150 dia. should be of the "link" pattern.)
1 set thread protectors for all tools.
1 set of copper casing thread protectors.

Wrenches.

2 tool wrenches for 140 mm. squares.
2 „ „ „ 120 mm. „
2 „ „ „ 110 mm. „
2 „ „ „ 100 mm. „
2 „ „ „ 80 mm. „
2 „ „ „ 60 mm. „
2 „ „ „ 50 mm. „
2 short hand wrenches for poles wrench square 40 mm.
2 long hand „ „ „ „ „ 35 mm.
1 catch wrench with steel key and chain.
1 catch wrench broad ribbed and brass inlaid.
1 chain lever, heavy.
1 chain lever, light.

Swivels.

1 pole swivel (ball-bearing type) for drill poles (draw line); box dimen. 35 mm. 46 mm.
2 pole swivels (ball-bearing type) for drill poles (draw line); box dimen. 26 mm. 37 mm.
2 sand line swivels; box dimen. 26 mm. 37 mm.
2 drill swivels (ball-bearing type); box dimen. 35 mm. 46 mm.
2 drill swivels (ball-bearing type); box dimen. 26 mm. 37 mm.

Underreamers.

1 Fauck style for operating in 9 in. Austrian standard casing.
1 „ „ „ 7 in. „ „ „
1 „ „ „ 6 in. „ „ „
5 Fairs spare cutters for 9 in.
10 „ „ „ 7 in.
20 „ „ „ 6 in.

Sand Pumps.

1 14 in., 2 mtrs. long, complete with valve. (N.B.—These sand pumps are usually made of standard Austrian casing.)
1 12 in., 5 mtrs. long, complete with valve.
1 10 in. 7 „ „ „ „ „
1 7 in. 10 „ „ „ „ „
1 5 in. 10 „ „ „ „ „
1 spare valve for each size pump.
1 cast steel casing clamp plate with 3 sets of wedges and wedge rings of 14 in., 12 in. and 10 in. casing.
1 ditto for 9 in., 7 in. and 6 in. casing.

Casing Swivels.

2 elevator clamps for 16 in. riveted casing.
2 casing swivels for 14 in. screwed casing.
2 „ „ „ 12 in. „ „
2 „ „ „ 10 in. „ „
2 „ „ „ 9 in. „ „
2 „ „ „ 7 in. „ „
2 „ „ „ 6 in. „ „
1 clevis and oval bolt for each size casing swivel.

Pulley Blocks.

1 5-sheave with hang irons and clevis sheaves 400 mm. dia. bronze bushed.
1 6-sheave with ball-bearing swivel sheaves 400 mm. dia. bronze bushed.
1 3-sheave with hang irons and clevis sheaves 400 mm. dia. bronze bushed.
1 4-sheave with ball-bearing swivel sheaves 400 mm. dia. bronze bushed.
2 single blocks with swivels.

Casing Slitters.

1 to cut downwards, adjustable for 10 in. and 9 in. casing.
1 „ „ „ 7 in. and 6 in. „
4 spare knives for each cutter.

Fishing Tools.

1 slip socket for drill poles with
7 bonnets for 16 in., 14 in., 12 in., 10 in., 9 in., 7 in, and 6 in. casing respectively.
1 horn socket with dogs.
1 rod hook with dog for poles.
1 rope spear.
1 wire rope grab.
1 fishing jar; diam. 70 mm.; stroke 500 mm., pin joint 35 mm., 46 mm.
1 sinker; diam. 65 mm.; 6 metres long.
1 full set spanners from 2 in. to $\frac{1}{2}$ in.
2 100-tons hydraulic jacks.

DISCUSSION.

The President said the Institution was greatly indebted to the authors for a very valuable paper. He would not attempt to enter into the technical questions because he did not understand them; but he was rather disappointed at the fact that the authors had made no reference to cementing, which was an important point in connection with drilling of all kinds. Another question to which he would like to refer was that of the supply of drillers. Evidently, from the knowledge that the authors had shown, there was no lack of engineers who understood the problems of drilling very well, but, as mentioned in the paper, the supply of Englishmen capable of carrying out the actual work of drilling was extremely small. That was a great discredit to this country in view of the enormous amount of English capital which was invested in oilfields. He knew that some very laudable steps had already been taken to overcome this difficulty, but, judging from experience, they were woefully inefficient, inasmuch as in 99 cases out of 100 we had still to rely upon foreigners to carry out our drilling work for us. That, he thought, was a difficulty to which the Institution ought to devote some attention in order to overcome it.

Mr. H. Barringer remarked that one point which interested him particularly was the material of which the tools were made. He understood that in the first instance iron tools had been used, shod with steel. They apparently seemed to have been discarded, and judging by the slides a good deal of trouble had evidently been caused by the breakage of tools now being made entirely of steel. He should like to ask whether, in regard to modern tools, welding of the steel tool to a wrought iron shank had ever been tried, or whether the same material was used throughout. He gathered the whole tool was forged from one billet. It seemed to him that that one quality of steel was hardly right to form the cutting edge, and to carry a truncated cone-connection which could stand the jar in working. That, he thought, was rather proved by a great many of the cracks extending through the thin portion of the water-way. He thought the question of the material for tools might be investigated. The cracking of tools was very often a common cause of complaint. He considered it opened up a field for a good deal of investigation, because the subject up to the present time had been rather given over to men of judgment, ingenuity and initiative, which were excellent qualities, but which he thought should be combined with a little scientific knowledge in the selection of material.

Dr. J. A. Leo Henderson said that to exhaust the subject, many papers such as here presented would be required. He joined the authors in emphasizing the importance of standardisation on the field, and the great need for care in regard to tool-joints. Students of oil-mining would do well to study such questions, which were of great importance in practical operations. He agreed with the authors that the question of fishing methods and appliances was one which lent itself to greater study and specialisation than was usually given to it. Its importance was often overlooked, and it would be a great advantage to the Institution if some member, who had devoted attention to that particular branch of the subject, would give the Institution the benefit of his experience in the form of a paper. In some oilfields presenting difficult drilling conditions, involving many fishing jobs, it paid to have a fishing specialist to take charge.

The standardisation of terms also claimed attention on account of varying terminology in use on different fields. Perhaps the Institution could take up the question, and submit suggestions or appoint a Committee to deal with the question of standardisation.

Mr. MacDougall said he would like to ask a question in connection with fishing tools: had the electro-magnet, suitably adapted, ever been utilised in operations of this character?

Mr. H. May said a very interesting point had been raised by the President with reference to the selection of Englishmen as drillers. He (the speaker) had had a certain amount of experience in this matter, but unfortunately the results had generally been unsatisfactory. He was inclined to think that the selection had been approached from the wrong point of view that a man trained as a mechanic or engineer would probably turn out to be a satisfactory driller. The American driller was, psychologically, of quite a special type, and he thought that if a little more attention was paid to the question of temperament, the results would probably be far more satisfactory. As a matter of fact the training of a mechanic was inconsistent with the development of the qualities requisite in a good driller. The mechanic was trained to take extreme care of his machine, whilst the driller's attention should be devoted to the deepening of the well. An intermediate course is obviously the most satisfactory. It had come within his experience that a man with mechanical training and gifted with the right temperament develops into a driller of the highest standard. This combination being, however, very rare he was inclined to think that in the selection of young men as drillers, temperament was more important than mechanical training. In this connection it had

to be remembered an American driller has seldom had any mechanical training other than that which he may have acquired during his apprenticeship at the rig.

The increased length of drilling bits was very largely due to the fact that a long bit was less liable to break than a short one, and that should a short bit break at the joint, it was far more difficult to recover by fishing tools than a long bit which would be less easily pressed into the side of the hole, and would stand vertically.

In the appended specifications there were one or two items to which he would like to refer. In no. 1, the authors said that an additional string of $5\frac{3}{16}$ in. casing might be included. In their specification the smallest diameter casing was $6\frac{5}{8}$ in. If the $5\frac{3}{16}$ in. casing were employed it would necessitate quite a number of additional tools with smaller joints than those specified.

One or two mistakes had occurred in the size of joints specified, for instance, under drilling tools the size of joint for the box of the 5 in. auger stem was referred to as $3\frac{1}{4}$ in. $\times$ $4\frac{1}{2}$ in., he thought this should be $3\frac{1}{2}$ in. $\times$ $4\frac{1}{2}$ in. The $6\frac{5}{8}$ in. drilling bit was specified with a $3\frac{1}{2}$ in. $\times$ $4\frac{1}{2}$ in. joint, he stated that this size joint was too large to go inside the $6\frac{5}{8}$ in. casing, and suggested that it should be $2\frac{3}{4}$ in. $\times$ $3\frac{3}{4}$ in. joint. He pointed out also that no 13 in. elevators were included, and also suggested that a rope grab would be a useful fishing tool to include in the specification in addition to the rope spear provided. He noted also that there were no spuds, underreamers or pipe swedges, all of which were useful tools, particularly in a field where several rigs were in operation. One very essential tool, hydraulic jacks, he pointed out, had been omitted.

Mr. C. B. Rosenplaenter enquired if there were any records available giving the length of the stroke of the tools with the Manila cable at certain depths. He had heard that in Pennsylvania in drilling for oil, galleries and crosscuts of coal mines had been passed, in which the action of the cable tools at depth had been observed, and measurements of the stroke of these tools are said to have been made.

Mr. R. B. Grey suggested electrical welding of casing. (See subsequent written communication.)

Mr. M. A. Ockenden replied as follows:—

In reference to the President's remarks, the subject of cementing did not come within the scope of the paper, which dealt only with plant. They hoped that some member, experienced in that subject, would at some future time read a paper dealing with the matter.

With reference to Mr. Barringer's remarks regarding all steel bits, the authors could add little information to that already given in

the paper. Difficulties were often due to inexperienced drillers in the field, handling high-class steel with inadequate appliances and a limited knowledge of heavy smithing.

The authors were glad to hear Dr. Henderson's remarks regarding standardisation of tools, tool joints and field nomenclature. If Dr. Henderson had any further observations to make on the point, they would be glad if he would convey them to the Journal in writing. Standardisation was a very important subject to the Institution.

Mr. MacDougall had referred to magnets for fishing. These had been used in largely developed fields, but their use could not be expected in prospecting fields. For fishing small pieces of metal, underreamer cutters, etc., electric fishing tools had been designed.

Mr. May had referred to the temperament of the driller. The authors agreed that the average engineer and mechanic, trained in the shops, was perhaps lacking in hazard, which was necessary in the successful driller. The authors thanked Mr. May for pointing out discrepancies in the specifications.

The authors had no information upon the question raised by Mr. Rosenplaenter. The actual stroke of the tool worked with Manila cable depended upon the elasticity of the cable, the weight of the string of tools (stem, etc.), the depth and, particularly, the amount of fluid in the bore hole.

In reply to Mr. Grey's remarks, electric welding had not been applied, so far as the authors were aware, to casing, but had been used in the welding of drilling stems and in pipe lines. A screwed joint was always preferred, because of the possible removal of casing, or the insertion of shorter or longer lengths at certain points, also on account of the greater facilities for "fishing" defective and parted casing.

On the motion of the **President** a cordial vote of thanks was accorded to the authors for their paper.

Subsequently, communications were received as follows:—

Mr. R. B. Grey: It occurs to me that electric arc welding plant would prove a most useful addition to the usual drilling outfit as well as general oilfield equipment.

A most important use in my opinion would be welding the casing joints, butt to butt, instead of the present method of screwed jointing. A continuous length of pipe would be secured, smooth internally and externally, with the welded joint as strong as the pipe and absolutely reliable. The cost of casing pipes would be considerably reduced as screwing would be eliminated, as well as the cost of the couplings.

An approximate estimate of the cost of welding, say, 12 in.

diameter pipe $\frac{1}{2}$ in. thick would be about 6d., and it could be done at the rate of about 30 ft. per hour, or about six minutes for a 12 in. pipe.

Electric arc welding plant can also be used for :—Welding plates, angles, bars ; repairing boiler plate wastage ; tank, drum making, and repairing tools. In addition to this it may be used for cutting pipes, plates, angles, bars, and any metal work.

A 15 to 20 kw. dynamo, supplying current at about 100 v., would suffice for all ordinary requirements, and when not in use for welding can be utilised for lighting purposes.

The welding plant can be made completely portable and self-contained, by coupling the dynamo to a suitable internal-combustion engine, mounting them together with the switchboard on a vehicle, or the dynamo can be driven by belt from any available power line. The welding outfit is then portable within the limits of the length of its flexible cable.

It appears to me that there is a wide and valuable range of work for electric arc welding plant in oilfield equipment generally.

Mr. Albert Millar : Under certain conditions there are many points in favour of all-steel drilling outfits, as they, as far as possible, meet the requirements of oil-well drilling where timber is very expensive or unobtainable, or where insect pests are troublesome. They can also be used successfully for the drilling of shallow wells, where, when once production has been brought in, a complete drilling outfit is no longer required. A steel drilling plant can be easily dismantled without difficulty and re-erected on the new site chosen for further drilling operations, and its place taken over the producing well by a light type of derrick, or suitable tripole erection for the manipulation of pump-casing, rods, etc.

Where, however, timber is obtainable, nothing is to be gained by the adoption of the all-steel derrick and rig for deep drilling, as the chief thing to provide is a derrick and rig of maximum strength, combined with that elasticity which superiority the authors admit that the wooden construction possesses over the all-steel outfit. The wooden derrick and rig for deep well drilling has in its favour the combination of these most essential factors—strength and elasticity—and is adaptable to all conditions. These two factors play a very important part in the successful drilling of deep wells, where long strings of heavy casing have to be manipulated, especially when one takes into consideration the fact that casing is often from 800 ft. to 1,000 ft. down, and the total length of such a string of 5 in. or 6 in. of heavy steel casing may run between 4,000 to 5,400 ft. and even more.

Certainly the all-steel outfit is very easily transported and erected, but I do not think even this point offers great advantage over the wooden construction, as I have known the rig builders to hand me over within 5 days from the placing of order, a derrick and rig of the standard heavy type suitable for a 5,000 ft. well, complete and ready for drilling operations to be commenced. Another very great advantage and economy is the fact that wooden derricks can be strengthened, should occasion demand, by a comparatively small outlay and loss of time.

I am sure it would be greatly appreciated by many of the members if the authors could kindly give some statistics and results of 4,000 to 5,000 ft. wells drilled with all-steel outfits in difficult geological formations, where the outstanding feature has been casing-troubles.

Substitutes.—Though most drilling tools and appliances have undergone many modifications, the substitute in general use remains practically the same. There is, however, a modified type, though at present little known, but which is a great improvement on the rigid bottle-shaped substitute for inter-connecting big calibre tools. During my experience I have never heard of one breaking, whereas, with the old type, breakages were a frequent occurrence, with the resultant fishing and loss of valuable time. This improved substitute has a link action, that is, the box and pin ends are made separately, the material to form the stems is drawn down to requisite size, then turned over and welded in the form of an eye, the one working in the other. I would recommend anyone who has had unsatisfactory experience with the old type to try this modified type of substitute, and I am sure the results would be satisfactory.

Drills.—The authors mention the tendency of manufacturers to make longer drilling bits. This is an important step forward for reasons which all those conversant with oil well drilling will appreciate. One method which is sometimes adopted, in my opinion deserves mention, and that is, to weld the drills directly to the sinker bar. This method has given great satisfaction, especially with the smaller sizes, 4 in., 5 in., 6 in. and, in some cases, 7 in. Also, I have never heard of this combination coming unscrewed from the jars, and a breakage seldom occurs, if ever.

Standardisation of tool joints, etc.—I think this subject merits the careful consideration of all petroleum technologists with a view to getting out a table of standard-sized joints for universal use, just in the same way as similar problems have been tackled. At present many manufacturing concerns have their own pet idea with regard to joints, which cause confusion when working, especially in centres where several manufacturers supply equipment,

each with their own special type of joints. On one important oil-field there are three different types of joints in common use, and it is quite a common occurrence when hiring or borrowing some special tool, to find that it has a different number of threads per inch, and will not connect with one's own tools. In my opinion, this has been the cause of many fishing troubles and consequent loss, even sometimes resulting in the eventual abandonment of wells, through careless drillers connecting two tools together having slightly different pins and boxes. The difference between the various manufacturers' standards is very slight, and really not one has any special advantage over the other, and I think it would be to the interests of all those concerned in the production of petroleum if petroleum technologists could see their way to take this matter seriously in hand.

Drillers.—With reference to the concluding part of the authors' paper, I think neither the highly skilled mechanic nor the common labourer make the best drillers, although some of the most successful Galician drillers are men recruited from the peasantry, having a certain amount of initiative combined with perseverance. I might mention that it takes the average Polish peasant from 5 to 8 years to master the art of drilling sufficiently to be able to get his driller's certificate, and after this, several years of practical application and experience is still necessary to make him a really competent man. The present moment offers a unique opportunity in England for Britishers wishing to get drilling experience. Working either as second or third mate to the driller, they would get a practical insight into this work, and if this were followed by the study of the various drilling systems, also of geology pertaining to petroleum, there is no doubt the average Britisher would make good progress. I am sure it is lack of opportunity and our isolated position which accounts for there being so few English drillers. Therefore, the present opportunity should be taken advantage of, to give likely men a chance, and I am confident results would justify the trial.

Lieut. A. D. Whitman: The suggestion for a paper on fishing operations is an excellent one. But, unfortunately, the professional fisherman (who is rapidly becoming as extinct as the Dodo) is usually a man that has spent his life on the "derrick stool," and is, as a rule, not one qualified to put the things he has in his head and at his finger-tips on paper. The best fisherman I ever knew was an old gentleman who could neither read nor write, but who had forgotten more about drilling than most drillers ever learn, and who had never lost a hole.

I believe that the reason no professional fishermen are being

made any more, is on account of the supply companies having a stock of simple and efficient fishing tools that the contractor can buy or rent, and that there were and are so many that profess to be fishermen who are not, that the contractor, as a matter of economy, would rather furnish the tools and let his regular drillers worry the job through to a finish. Therefore, every driller to-day must be more or less a fisherman to be a good driller. There are a few good fishermen left, but they are only called upon when a valuable well has gone bad, and usually after the regular crew has made the job a hopeless one. They usually command between 50 and 25 dollars per day, and very seldom, if ever, contract to leave a clean hole.

Paragraph 5 in Conclusions is well taken. I can readily imagine difficulty in translating "alligator-grab" or "horn-socket" into a foreign tongue. But I honestly see no remedy. Some of these tools had their name before our time, and will probably have the same as long as they are used.

The "concave cutting edge" (paragraph 3 under "Bits") is often called the "feather edge."

First Annual Dinner of the Institution.

The first Annual Dinner of the Institution of Petroleum Technologists was held at the Connaught Rooms on Tuesday, March 25th, 1919. **The President** (**Mr. C. Greenway**) occupied the chair, and was supported by a large number of distinguished visitors and members, including the Rt. Hon. Lord Moulton, P.C., K.C.B., G.B.E., F.R.S., the Rt. Hon. Viscount Cowdray, P.C., Sir Boverton Redwood, Bart. (Past President), Rear-Admiral Sir Hugh H. D. Tothill, K.C.M.G., C.B., Sir Frederick Black, K.C.B., Admiral Sir Edmond J. W. Slade, K.C.I.E., K.C.V.O., Brigadier-General R. K. Bagnall-Wild, C.M.G., Sir Henry Belfield, K.C.M.G., Sir John Cadman, K.C.M.G., Major A. Cooper-Key, C.B., Captain R. Whieldon Barnett, M.P., Mr. G. E. A. Grindle, C.M.G., Mr. T. C. Palmer, Prof. J. S. S. Brame, Dr. F. Mollwo Perkin, Mr. Arthur W. Eastlake, Mr. H. Barringer, Dr. Dunstan and Dr. W. R. Ormandy.

"HIS MAJESTY THE KING."

The toast of "His Majesty the King," proposed by the President, was accorded musical honours.

"THE INSTITUTION OF PETROLEUM TECHNOLOGISTS."

The Rt. Hon. Lord Moulton, P.C., K.C.B., G.B.E., F.R.S., in proposing the toast, said:—Mr. Chairman, Lord Cowdray and Gentlemen, I do not know why I have been selected for the honour of proposing the toast of The Institution of Petroleum Technologists except that it is that the members prefer such a toast as this to be proposed by someone who is outside their ranks, and who at the same time is as great a fanatic about petroleum as themselves. (Laughter.) If that be the principle of choice, I qualify. I am undoubtedly outside your ranks; I wonder at the knowledge you represent; I admire what you have done, and I feel that you have the honour of working at questions the importance of which to mankind at this moment and for many years yet can scarcely be exaggerated. (Hear, hear.)

I remember when I first began really to appreciate the capacities of petroleum. I of course had known it as supplying a most valuable illuminant capable of being distributed throughout all civilisation. I remember when I went as one of the Commissioners to the Chicago Exhibition, and there I saw the whole of the power-installation which supplied the electric light to that enormous Exhibition, and did everything else that it was asked to do; and I discovered that the whole of the fuel was piped for a great number of miles, and was used under the boilers, and that solid fuel coal, which, up to that time, was the only thing I had associated with steam, was never thought of. That gave me an idea that in peace petroleum had a very much larger realm of utility than I thought.

The next lesson I received was once when I remember I met Admiral (now Lord) Fisher at Marienbad. We used to take walks together, and talk about all sorts of things, peaceful and military, and one day he quietly remarked to me: "The use of liquid fuel adds 50 per cent. to the value of any fleet that uses it, because one-third of the time of every war-vessel is spent in coaling, and that means that if it does not use liquid fuel it must return to port."

Thus its importance in war was brought home to me, but I had a third lesson to learn about it. I had to realise that in order to be useful for lighting, in order to be useful for power, and in order to be useful in the Fleet, your petroleum must be a respectable fluid of high volatilising point, so that it could be kept without danger. I am quite aware that it penetrated even into the domain of politics, and I remember an excited debate in Parliament, in which I am ashamed to say I remained silent, in which the Government was being attacked for changing, in a way utterly regardless of human

safety, the flash-point of petroleum, so that instead of its being a high temperature it was a low figure. I listened to the debate with great amusement, because I knew perfectly well that no change whatever had been made except in the instrument for measuring it. (Laughter.)

The fourth lesson that I received was closely akin to the question of the flash-point. When the internal-combustion engine came, we saw a method of stepping through gas to a most convenient form of engine, very economical in its use of fuel; and the lighter petroleums, the extremely volatile fluids, showed themselves quite equal in manageability and in effect to gas—in fact, more powerful than gas. I at once said: "Here is a chance for the highly volatile petroleums; they must be exceedingly valuable."

I was once more shaken by the statement of a very competent man, "No petrol engine is worth anything; you cannot run the risk of keeping a volatile fluid for that. If you are going to make petroleum suitable for internal-combustion engines, you must take the ordinary petroleum, not more volatile than that which you burn in lamps." That was before motors came in. When motors came in, the world found that this rejected form of petroleum was invaluable, and that if the change from horse traction was ever to take place, it must be through the despised form of petroleum. Now the thing the world is most anxious about is that there should be a supply of this volatile, or, as you might say, dangerous stuff. So that I had learned that the heavy petroleums, that the moderately volatile petroleums, and that the extremely volatile petroleums each had their place in civilisation and a place which nothing else known to us could take. (Cheers.)

From that time my thoughts about petroleum were of a very simple character. I realised that Nature allowed mankind to grow up in ignorance of her wealth, that there was stored under the earth valuable material that mankind did not dream of till coal was found. Now the result of the discovery of coal by its use in steam was to tell the world for some unknown number of centuries that it could get brute force as cheap as it liked; and the consequence was the whole of mankind, and the whole of the mechanical geniuses that were amongst us, set to work to make all the operations that we desired to perform a question of mere brute force. They took lace that you saw done on wee dainty little bobbins and with dainty fingers on a pillow, and they gave that in charge of a heavy mass of iron moving about in almost inextricable complexities of machinery. Why? Because the question of whether it took much force or little force had been settled by the discovery of coal

and its uses, and all that they wanted to do was to teach this brute, no matter at what expense of brute force, to do the dainty things that had been done always by avoiding anything that was burdensome or heavy. One thought that when Nature had shown us that, and the whole of civilisation was changed by it, she had told us all the fortune she had for us. We knew perfectly well that the strata that we met with were not going to assist us in tasks like that; and I think everyone who considered the future of the human race based the duration of its "rake's progress" on its indulgence in its wealth of coal, and how long it would last. But Nature had something behind which was still the cream of its gifts. It had yet to tell us of the stores of liquid fuel that were hidden in the earth, and how we were to use them. The liquid fuel which we call by the general name of petroleum is the cream of Nature's gifts in this way. It is positively the luxury of fuel for those who know how to handle each form of it, because it is so important that we adapt our methods to it. It would seem as if in this liquid fuel Nature had pitied us, and had given it to us in a form in which we could use it more effectively, more freely, and with a wider field for its use than in any other way. I have had occasion to think a good deal of what—if I may use a phrase which is very common in the chemical industry—we call intermediates, that is, one of those fundamental products and fundamental compounds which you make before you begin the serious work of making the final compound that you are seeking. I have had to consider a great deal what I should call Nature's intermediates, about the way she steps from the elements into that which is directly capable of being used for mankind. We all know it in a very different sphere, nitrogen, which lazily occupies four-fifths of the atmosphere, doing nothing—absolutely useless—until you coax it from its isolation, and get it to combine, say, with oxygen or with anything else. As soon as it has combined you run it through all the channels that you desire from a strong alkali like ammonia to the fiercest of all acids, nitric acid. But as long as it is uncombined, there it is, idle and useless. In a different way you might almost say the same of the great element called carbon. Carbon is unexcitable. I do not think anything looks less lively than a lump of carbon. It is almost not to be tempted out of its isolation and its restfulness, and yet Nature makes it the foundation of nearly everything in organic life. And how? She marries it to hydrogen in some form or other, and it is from the marriage of carbon and hydrogen that she starts in almost everything. The whole realm of colour comes from her through what they call the aromatic series, through benzol

and toluol, and through petroleum starting from a similar marriage as paraffin. Nature has given you in that way in its most manageable form, a fluid form, an innumerable list of these compounds of carbon and hydrogen, and almost challenges you to make proper use of them. Take up any book which gives the progress of organic chemistry and you will find that it starts from this compound of carbon and hydrogen in every single chapter. Turn to those dealing with the mechanical effect of fuel, and you will find that that which determines its value is the presence of these compounds with which you have to deal in their most naked form. When I consider what has been done with the aromatic series, which does not so frequently appear among petroleum products, and when I look at the fat books full of unintelligible names and heaps of structural formulæ of what is called the aliphatic series, I begin to wonder where it will stop. I am perfectly certain of this—that you cannot take anything widely distributed in organic life, or I might say almost in inorganic matter, which involves carbon, but you will find that it commenced by a marriage or a liaison with the fascinating hydrogen. (Laughter and cheers.) So much for the origin of petroleum.

Now let me for one moment give you my estimate of its importance from my experience in the war. If it had not been that in one type of petroleum, that obtained from Borneo, there was a considerable proportion of benzol, my face would have grown permanently an inch longer, and the small amount of hair which I still claim must have gone, for I should not have known how to keep up with the gigantic demands of our Services for high explosives. At the same time I knew perfectly well that work quite as important was going on in other directions than explosives, for you must remember that these marriages between carbon and hydrogen are rather of a character which used to be attributed to the English people with regard to their marriages—that they used to swap wives. (Laughter.) It is well known that work has been done on the transforming of one compound of hydrogen and carbon into the other, so that you can from a given petroleum produce something very much heavier which you can use as fuel, and something very much lighter which you can use for motor purposes or for illumination. What is more, we have had hopes that you could change it from the one type, paraffin, to the other type, benzol, but I am sorry to say that those hopes have not yet been much fulfilled. There is one thing, however, that is settled in my mind. They may not be able to do it yet, but I am satisfied that the true name for what is called by all of you "destructive" dis-

tillation, cracking and that kind of thing, ought to be "constructive" distillation. You build up new products, and it is only from want of skill that you cannot build up whatever product you want. That want of skill will pass away, and we shall look upon the petroleum that we get as the source of all those compounds of hydrogen and carbon that we need for our future labours. Therefore, I regard petroleum as the most valuable source of the raw materials of chemical organic science.

So far I have been showing you that I am fit to propose this toast because I have an enthusiasm for petroleum. But I am not drinking the health of petroleum; I am drinking the health of this Society, with the sonorous name of "The Institution of Petroleum Technologists," and I have got to show you how an enthusiast for petroleum is an enthusiast for petroleum technology. I can do that easily. Of all the things that mark petroleum as against anything else that we get out of the bowels of the earth, the chief are that it is the most easily wasted, the most difficult to locate, and, I am afraid, the most precious on account of its scarcity. There is no body of technologists who have the duty of speedily bringing themselves up to the highest standard in a greater degree than have petroleum technologists. They have got to stay the hand of the world which would waste petroleum. It is far too precious for that. They have got to seek out and secure that all the resources of science are given to doing its work well. We can wait for coal. There are plenty of seams and plenty of districts so rich that we can get our coal, and what is left is, to a certain extent, not entirely incapable of being retrieved later. When you once start on a petroleum field, however, unrestrained boring and wasteful methods leave beyond the power of human recovery vast quantities of this most precious gift of Nature. I feel impressed by the skill that enables people to locate the position of petroleum deposits. How you are going to tell what is under the ground, which was put there millions of ages ago perhaps, and which is covered by deposits that have taken all those millions of ages to form—how you ascertain it really puzzles me; and yet I know that you have attained to a great skill which enables you to form a just conception of the probability of finding petroleum. The way that knowledge is used is of the greatest possible importance to the world. You must feel that on your shoulders rests, not only the getting of this petroleum, but the leaving of the world as little poorer for what you have got as is possible. There are people who hope to find it in England, and I hope that their expectations will be fulfilled. Nothing would please me more than to find that

the nation as a nation realises the gravity of searching for it and beginning to get it, that it should not be left to unrestrained individualism to try and potter about in order to get it, because, although I am a stern individualist, I look at these sources of petroleum as part of the wealth of the inhabitants of the world, which they have a right to say must be husbanded. Therefore, when I am speaking to petroleum technologists I want you to feel the responsibility of the work that is in your hands. Woe to you if you are not alive to the importance of it! I remember a great surgeon who was reporting to his class on two difficult operations that he had performed that morning, both of which had failed, the patients having died. He said to his class: "I could never forgive myself for those two deaths if I could not feel satisfied that I have never neglected an opportunity of perfecting myself in my profession, and that therefore the blame does not rest on me." I want something like that to get hold of you. Petroleum is a gift necessarily small in quantity, having enormous importance to existing civilisation, as I have indicated. You are the people who will have to determine how it is to be sought for, how it is to be won, and you ought to feel that any waste is your fault if you ever neglect an opportunity of perfecting yourselves as petroleum technologists. In this sense I propose prosperity to The Institution of Petroleum Technologists. (Cheers.)

The President, in responding, said: I rise with great pleasure to respond to the toast which has been proposed so eloquently and learnedly by Lord Moulton, but I do so with a good deal of diffidence as I feel that it would have been much more fitting had it been responded to by our distinguished friend Sir Boverton Redwood, to whom the Institution owes not only its inception but its present vigorous existence notwithstanding the difficulties created by the war.

I have always felt, as I have mentioned on other occasions, that the holding of the Presidential Chair by me—a mere commercial man—of an Institution of such highly scientific and technical membership as this was an anomaly. At the same time I have regarded it as a very great honour, and I can assure the members present that I have its welfare sincerely at heart, and shall always do my utmost to promote its interests. There is no technical Institution in the country that I am aware of which is more badly needed than this. Though the British nation is to the fore in most other branches of industry, in the technology of Petroleum we are woefully behind—not so much on its scientific side, for in this direction I venture to state that we are not one whit behind any

other country—as in the want of a sufficient supply of the Geologists, Field-Managers, Drillers, Refining Managers, Chemists, Engineers and other technical men necessary for the proper development of the industry under British auspices. This is all wrong. There is an enormous amount of British capital now invested in the petroleum fields of the world—both inside and outside of the Empire—and this capital should be utilised as far as possible in providing employment for Britishers, and not, as is the case very largely to-day, in the employment of foreigners. To me it has been a constant source of disappointment that we find it quite impossible to recruit in this country the large number of technical men required for the carrying out of the work of my Company, and that we either have to go very short-handed, or recruit in other countries. What is the reason? It cannot be the question of remuneration, because in the oil industry the remuneration of technical men is, so far as my experience goes, on a more liberal scale than in other industries. The explanations are, in my opinion, twofold. Firstly, that the facilities for securing the requisite education, and more particularly training, are not so great as in other countries interested in the oil industry; and, secondly, that the opportunities of finding remunerative employment in the oil industry are not sufficiently well known in this country by young men in search of careers.

But how are these difficulties to be overcome? The first is one that this Institution was created with a view to endeavouring to surmount. It has already done a good deal in the direction of centralising attention on the industry, and in what I may describe as the higher education, by affording opportunities for the interchange of ideas and information among fully-qualified experts, and this has no doubt all been greatly to the common benefit. But a good deal remains still to be done in the direction of increasing the primary educational and training facilities in this country for persons desirous of taking up as a career any one of the technical branches of the industry. In the Memorandum of Association of the Institution one of the objects for which the Institution was established is described as being

> "to promote the better education of persons desirous of becoming professional consulting petroleum technologists, petroleum engineers, geologists or chemists,"

and I would urge very strongly that this object, now that the war is over, and that everyone is more free to consider industrial problems, should be pursued by the Council of the Institution energetically and in a practical way, and I would suggest that this can best be done by the constitution of a sub-committee empowered

to enquire into the best means of promoting the object in question, and to formulate a scheme for submission to the principal Oil Companies. I would make the further suggestion that this committee should be asked to consider the words "and training" as inserted after the word "education" in the paragraph which I have just quoted.

The directions in which this education and training can be best promoted will of course require careful consideration and working-out, but I am quite sure that if a satisfactory scheme can be evolved, it will receive the hearty approval and support of all British Oil Companies, for we all feel badly the need of a larger and better trained supply of British petroleum experts.

In putting forward these views I am not, of course, overlooking the most excellent work which has already been done in the same direction at the Birmingham University by our late President, Sir John Cadman, but this covered only a part of the ground I have indicated, and in any case was too local and on too small a scale to fully meet the needs of the industry. Moreover, I am sorry to learn from him that it has been to a large extent, if not entirely, nullified by the war. But the experience he has gained of the subject, both at Birmingham and in his present post of Director of the Petroleum Executive, would be of great value in the consideration of some more comprehensive scheme of education and training, and should, as I have ventured to recommend, a committee be formed to deal with this matter, I hope that he may be able to join it, and give it the benefit of his views.

The second difficulty, the want of knowledge as to the splendid openings which exist in the oil industry for men of the requisite education and training, is one that could and should be overcome by suitable propaganda among the Universities and other educational Institutions of the country. One speaker at a recent meeting of the Institution suggested that the reason why there is, for example, such a dearth of British drillers is that the British engineer or mechanic who is usually accustomed to town life is not so ready as his American cousin to put up with the comparative solitude of existence on an oilfield. I don't accept this explanation. The Britisher has always been as much imbued with the spirit of adventure, and as ready to seek his fortunes abroad, as any man in the world, and if we can open up the proper channels to enable him to qualify for the different branches of the industry, there will, in my opinion, be plenty of suitable men available for carrying on the whole of the work connected with the now rapidly expanding British oil industry.

Before I sit down, I would like to express the great pleasure it has given to me to act as the President of this Institution for the past two years, and to thank the ex-Presidents, the Honorary Secretary, and the members for the unfailing courtesy and assistance which I have at all times received from them during my period of office. I would particularly like to take this opportunity of drawing attention to the valuable services which have been rendered to the Institution by Mr. Arthur W. Eastlake who has acted in the capacity of Honorary Secretary since its inception, and has done yeoman work in the direction of maintaining the usefulness and scope of the Institution during the war, notwithstanding the falling off in membership which has necessarily resulted therefrom. I would further like to pay a tribute to the valuable services rendered by Mr. Dalton as Editor of the Journal and as Librarian. Mr. Dalton is entirely responsible for the success of the Journal, the value of which is amply demonstrated by the large demand which exists for copies of it from all parts of the world. He has also done very valuable work in arranging and cataloguing the Library in such a manner as to make it quite easy for reference.

In retiring from the Presidentship, it is a matter of very great gratification to me that I am to be succeeded by so able and distinguished a member of the Institution as Sir Frederick Black. As you all know, he has had a great deal to do with petroleum matters during the past few years, both on the commercial and technical sides, and I am sure that he will prove to be a pillar of strength to the Institution, and a far more worthy occupant of the post than I have been. (Cheers.)

"THE GUESTS."

Sir Frederick W. Black, K.C.B., in proposing the toast of "The Guests," said :—Mr. President, my lords and gentlemen, I think the President's selection of someone with whom to couple this toast must have been rather a source of embarrassment, but I do not think he could have found a better name than that of Sir Hugh Tothill, with whose name I have the honour of coupling it. In choosing the Admiral and myself he has in one respect chosen rather dangerous companions, because we are both silent men from that silent Department, the Admiralty. The way we should like to propose and respond to this toast would be something like this : I would like to say, in Navy fashion, "The Guests, God bless 'em !" and the Admiral would respond by saying, "Thank you all, pipe down !" (Laughter.) Your choice reminds me of a dilemma

upon which I once heard Mr. Bernard Shaw wittily dilate. He said that if one imagined such a distinguished couple as, say, the Archbishop of Canterbury and General Booth engaged upon a particular duty, and the work connected with that duty fell away so that there was only enough for one, how would a person manage to choose between the two as to which should carry on the duty? In that case, he said, the choice would be as embarrassing as if he had to choose between such eminent companions as Mr. Marshall and Mr. Snelgrove. (Laughter.) I think there are many here to-night, particularly Lord Cowdray, who should have been called upon to deal with this toast as well as the Admiral and myself.

The reason for choosing Admiral Tothill was probably this—not only because of his great personal merits and his active service on behalf of the Crown during the war, but because he is the representative of the British Navy, and carries on his shoulders the great burden of being the Fourth Sea Lord of the Admiralty. (Hear, hear.) I have known something of every Fourth Sea Lord for the last 30 years: I have assisted them in their duties in regard to the fuel of the Navy, both coal and oil. I remember Admiral Sir Arthur Moore, who performed great services during the Boer War, when our problems were very difficult, but not quite so difficult as the problems that have faced us recently. Admiral Tothill stands at the head of all the great Fourth Sea Lords of whom I have known. When I think of him in connection with oil and his cheerful optimism, I am reminded of the famous saying of King David about oil, that it caused man to have "a cheerful countenance." (Laughter.) I think the mantle of prophecy was on King David's shoulders when he used those words, because right away down the vista of the future, at the end of a very long avenue, he saw the smiling face of Admiral Tothill. (Laughter.)

One of the feats which Admiral Tothill performed with the assistance of our American friends is not perhaps very well known. Scotland stands no longer where it did: Scotland is now divided into two parts—north of the pipe and south of the pipe. (Laughter.) There is a thin pipe, only 32 miles long—not like the great American pipes, 1,200 and even 2,400 miles long that Lord Moulton has spoken about—and the pipe is filled with a thin stream of American oil. Admiral Tothill emulated in that respect the great feat of the Roman general, the Emperor Hadrian. The Emperor Hadrian built a wall across Scotland to prevent the Picts and the Scots from coming south to London to make their fortunes—(laughter)—as many Scotsmen have done since, and will continue to do till the end of time. (Laughter.) I think a child could jump over this par-

ticular pipe, and I do not think it will prevent a Scotsman from coming south. (Laughter.) In fact I sentimentally regard that pipe as a bond of union rather than a division, because it joins the Clyde and the Firth of Forth together, and it saves a good deal of tonnage from going round the north of Scotland in a wasteful way.

Speaking of the British Navy and what it has done during the war, I do not think I ever heard the services of the sailor better expressed than I did once in New York. I was witnessing a theatrical performance given by the sailors of one of their training ships on a Saturday afternoon on behalf of the Actors' Benevolent Association, and the chairman of the Association, in receiving a cheque for some three thousand dollars as the proceeds of the entertainment, made use of this expression: "I always have confidence in the sailor; in circumstances the most difficult, he remains master of the situation." I think that sums up what the sailor has done at all times—not only the sailor of the Royal Navy but the sailor of the Merchant Service, particularly during this war. (Hear, hear.) It is not necessary to dwell upon this subject, because the great services of the British Navy remain among the imperishable, historic, glorious memories of our race that shall endure for all time. (Cheers.) At the beginning of the war, thanks to the Navy, the sea was cleared of the German merchant flag, and the German flag over its warships was not greatly seen upon the ocean. The Navy also, in course of time, tackled the serious danger of the submarine. I will not bore you with statistics, but there is just one fact I would like to mention to you. I have taken out a very rough approximate figure of the amount of coal moved out from the United Kingdom over the seas during the war, not merely for naval and military and transport, but for all purposes, and it amounts to about 250 million tons of coal in 4¼ years. I suppose one-third of that amount may have been used by the naval and military services that I have spoken of. The quantity of petroleum oil moved into European waters from over the seas during the same time was about 30 million tons. (Cheers.) I think that fact alone speaks eloquently for what the Navy did in keeping open the seas to transport.

Lord Moulton has spoken about the merits of oil generally, and there is nothing to add to what he said except what Admiral Tothill may wish to tell us about its special uses for naval purposes. I was very glad to hear Lord Moulton refer to that distinguished naval officer, Lord Fisher. Sir Boverton Redwood, and I in particular—and some others also in this room—will remember what Lord Fisher did in connection with oil fuel for the Navy, particularly on the

Royal Commission of which he was the head. There was one service he did that was quite remarkable. If any of you gentlemen have had to go down to the committee rooms of the House of Commons to give evidence, you know that all the members of the committee who ask questions sit round a horseshoe table, and the unfortunate witness is put at a small table at the end of it, entirely alone. Lord Fisher said: "I will not have that parliamentary procedure; I will have a round table," and all the witnesses who came to give evidence about petroleum were put on Lord Fisher's right; alongside of him was his secretary and all the necessary books and papers, and he put the witness entirely at his ease, and encouraged him to get information from his secretary and papers. The result was that he acquired information in that way which could not be dragged out of a witness when he is treated something like a prisoner in the dock. (Hear, hear.) Then Lord Fisher used to use forcible and picturesque expressions which I am sure Sir Boverton Redwood would carry in his memory as well as I do. He used to say to us: "It will be almost more important in war time to bring in oil than to bring in food, because if we bring in oil, then the food will come in too." He used to speak of oil in such phrases as "potted energy" or "the Oxo or Bovril of fuel." One cannot but wonder at the way in which all his anticipations have been realised in this respect. One marvels at his great foresight and the great results which have been achieved. No living man has done so much for the Navy and its organisation in the provision of all necessary material as he has done in this war.

I would have said a word about Lord Moulton and his connection with oil in the High Explosives Department over which he has presided, but he has dealt with that point for himself. If we could only get Lord Cowdray to tell his story of the great Mexican enterprise and something of the difficulties that he struggled with, and the divers opinions that he had to face when he started to build the great tankers which have been invaluable during the war, it would have been of the greatest interest to us. We should like to know what he thinks about the possibility of finding oil underneath the soil of England, because not even Sir Boverton Redwood has been down an oil-well casing to find out what there is at the bottom. (Laughter.) We should like to hear Colonel Bagnall-Wild on the subject of what aviation spirit has done during the war. And here I should like to express to him, and everybody connected with him on the Air Board, thanks that they did not press for an unduly difficult specification. They kept what is known as the "end point" at a very reasonable figure that the refiners could deal with,

because we had to go to many of the American refineries in particular to produce a very high grade of aviation spirit which they had not been accustomed hitherto to produce, and if they had been asked to produce the very difficult "end point" that was asked for in certain small quantities, it would have enormously reduced the possibility of America assisting us in the way she did, because it would so much have reduced the output of any given refining plant.

Another point that I should like to mention is that oil, besides adding enormously to the efficiency of the Navy, Motor Transport and Air Service, has actually been the means of saving many valuable lives during this war. Anyone who has gone to and fro through oceans infested with submarines, as I have done (I have passed four times through submarine-infested areas during this war), will realise what those men who work in the engine-room and the stokeholds have had to endure—the courage that they have shown in sticking to the engines and the stokehold when, if the ship had been torpedoed, they probably would not have had a dog's chance of saving their lives. The tales of heroism that I have listened to on the part of men who have served in the engine-room in torpedoed ships are among the high romances of the war, and equal to anything that can be told of exploits in the air or in the trenches. I used to say very often to my friends in America, when I was pressing them very hard for more tankers and more oil, that the sailors and ships were the pillars of civilisation—the pillars upon which the ordered protection of the world then rested. In talking of oil as a pillar, I am sure my friend the Engineer-in-Chief of the Navy would say that I must be speaking metaphorically, because he does not like oil as solid as to constitute a pillar in the ordinary sense. (Laughter.) I am sure the thanks of the Allies ought to go forth to everyone connected with the oil industry, such as petroleum technologists and the great Oil Companies, British and American, that have supplied us with the large quantities of petroleum products that have been necessary in this war, and I do not know of anyone to whom our thanks are due more than to Admiral Tothill, who has been guiding us in a friendly way right through this war. When I was in America I was in active communication with him, and sometimes he used to tell me I was taking rather too active an interest in what was going on at this end. I do not mean to say that he suggested I was not looking after the business at the other end, but I used to send over to him what he called "clever American notions," and he told me, "What we want from you is oil and tankers." (Laughter.) With regard to the pipe-line, we owe a very great deal to Mr. Forrest Toll and

Commander Bristow of the United States Navy, who came over here with a party of about 120 men, when it was difficult to find the men to do such work. They brought with them about 4,000 tons of material, and it took all that material to make a little pipe-line about 32 miles long. You may guess what was the pressure in America to provide that new pipe-line, and what must have been the pressure produced in making the great line which runs from Oklahoma down to the Gulf of Mexico in one direction, about 600 miles, and up to the refineries at Tulsa, Okla., which supplied the oil, another 600 miles, and then about 1,300 miles down to the Atlantic coast, in all about 2,400 miles of pipe-line in order that oil might be brought to the seaboard for transport to Europe and the rest of the world. I do not think we can be too grateful to all these great companies for the help they gave us. My American friends used always to say to me, "You must prove your case." We had to show that we really wanted all this oil; we had to show them that we were using our tankers in the most economical way; and when we had done that, they made up their minds they would never let us down. I am not, I hope, suggesting that the American Companies did better than the great British Companies. The Mediterranean was largely supplied by the Company of which our President, Mr. Greenway, is Chairman. The other great group, the Shell group, gave us very valuable help with that particular oil out of which, as Lord Moulton has told us, toluol for high explosives was extracted. The co-operation of the Americans and our own oil Companies was successful in finding the oil that was necessary for the safety of civilisation. (Cheers.) I have much pleasure in asking you to drink to the many distinguished visitors whom the Institution of Petroleum Technologists welcome here to-night at their First Annual Dinner, and to couple with the toast the name of the man who has borne as great a burden as any living Englishman during this war, Admiral Sir Hugh Tothill, the Fourth Sea Lord of the British Navy. (Cheers.)

(The toast was duly honoured).

Rear-Admiral Sir Hugh H. D. Tothill, K.C.M.G., C.B., in responding, said :—

Mr. President, my lords and gentlemen, I feel it is a very great and very undeserved honour that I should be chosen to return thanks for all the distinguished guests that you have so kindly invited to your hospitable board this evening. Returning thanks is a task which I approach with the very greatest diffidence, not only because as a sailor and as a member of that Service which perhaps not altogether unjustly claims to be silent, I am no hand

at speaking, but also because I find myself in the position of addressing a body of experts as a layman on a subject on which I was until quite recently profoundly ignorant, and on which, in spite of my having been Fourth Sea Lord now for nearly two years, I am only too conscious that I am still very lamentably uninformed.

My first actual connection with petroleum—and naturally to a naval officer petroleum most appeals in the form of fuel oil—was when I went down to the House of Commons in 1913 to listen to an extraordinarily lucid speech made by the then First Lord, Mr. Winston Churchill. It was only then that I learned for the first time that His Majesty's Government had embarked on an oil policy of their own, and that it had invested a considerable sum of money in the Company over which your Chairman so very ably presides. I would venture to say, gentlemen, that that policy has been a great deal more than justified by the course of this war. I think that the holding the Government had in that Company, and the support which they have at times been able to afford it, has rendered us invaluable assistance in a situation than which none could have been more difficult.

I have never myself had the good fortune to command a ship that was fuelled entirely by oil, and I have often envied my brother officers who have had that good fortune. You can well understand what a difference it makes to the comfort of the officers and the men. In the early days of the war we used to go out into the North Sea to carry out what we called a "sweep," and on returning from the sweep, which was almost always perfectly fruitless, the first thing to do was to fuel the ship up again. Naturally, we had to fill up the ship with all its stores, ammunition and so forth. In the case of the happy people who served in a ship that was run upon oil alone, when they got in many hundreds of tons of oil were pumped through the side, and hardly anybody knew what was going on. But there was a different tale to tell when a ship had to hoist in a thousand tons of coal. That meant a large amount of work and a dirty and laborious job. At the same time one must admit that the advantage was not entirely on the side of oil. The getting in of this coal provided first-class physical exercise for all hands. Practically everybody took part in it, in fact I think the captain was the only officer in the ship who did not do any of the manual operations, but he observed them with an interested eye. It also afforded an excellent means of promoting that invaluable spirit of emulation and competition between the ships, a spirit which was absolutely invaluable in preserving, not only the discipline, but the good comradeship and the well-being of the ships' companies

during the rather cold and monotonous days. Whenever we reached the 300-ton an hour limit, it was a source of the greatest gratification to everybody, and when we were the top ship of the squadron, everybody was particularly proud and happy for the next week. So that it really did fulfil a useful purpose, though I must admit I would have preferred oil. (Laughter.)

The first time I ever experienced any feeling of gratification about oil was on the 31st of May, 1916. On that particular occasion we were carrying out another of our sweeps. There was nothing to indicate trouble would ensue; it was a beautiful fine warm day. The first indication we had that we might hope to have a little more luck than usual was when we gradually began to increase our speed, and at a not very late hour we had arrived at a speed that tried the powers of some of the older ships to the fullest extent. My particular ship was a very good steamer. The engineers were absolutely excellent, indeed the whole department was, so that I was well satisfied, in spite of the fact that I was not an oil-burning ship. But owing to some slight defect in the engine-room telegraph, when we increased speed the correct number of revolutions was not registered in the engine-room. Proceeding at such a high speed, and the ship being enormously weighty, it takes a little time to lose your maximum, and it takes a damned long time to pick it up again. The result of this was that, to my surprise, I found I was gradually dropping astern. Thereupon I immediately made enquiries, and I had hardly done so when I was horrified to see a signal go up on the Commander-in-chief's flagship: "If the 'Conqueror' cannot maintain her station, she is to be passed by the 'Thunderer'"—that was the boat next astern. You can imagine the feelings of myself and all the officers on the bridge! But no sooner had the indicator been put to "Full speed ahead" than the ship almost leapt at it, entirely due to the fact that, although she was a coal-burning ship, she was also fitted to burn petroleum. But for that fact, I could not have kept my station.

I remained up there till I was promoted as Fourth Sea Lord at the Admiralty, and when I arrived here I found the situation not a little delicate in regard to petroleum, so far as it affected the Admiralty. At that time the German submarine activities were at the height of their success. The daily sinkings were really alarming. The enemy seemed to pay special attention to the tankers, which were going down in enormous quantities. The reserve of oil was falling very rapidly, in fact the situation was exceedingly black. I ask for a little sympathy for myself because I arrived at the Admiralty totally ignorant, practically speaking, of everything

connected with petroleum. My responsibilities would have been almost unbearable had I not been surrounded by a staff of civilian gentlemen in the Admiralty, the Director of Contracts, Sir Frederick Black, and also the Director of Stores, whose zeal, devotion to duty, ability and knowledge of the whole problem from A to Z is, I venture to say, unequalled. In this connection I cannot fail to make an allusion to my friend the late Mr. Waller, who was Director of Stores. Mr. Waller was the second Director of Naval Stores who lost his life owing to his devotion to duty in this way. When I joined the Admiralty he had already been on leave for many months, having completely broken down, but being the devoted public servant he was, he absolutely declined to remain away until he was completely recovered ; and when I arrived there, although he was palpably far from well, I found him the same able, cheerful, resourceful and devoted public servant as ever. Sir Frederick Black has been kind enough to allude to what I think he called my "cheery cussedness." There is small merit in that so far as I am concerned, because he and Mr. Waller, not only preserved the most cheery and confident optimism during the war, during all these very anxious periods, but Sir Frederick imbued the whole of his staff under him with the same spirit, and that very largely assisted in a most delicate situation.

The situation, I must admit, did not mend itself very shortly after I joined the Admiralty. Matters appeared to be going from bad to worse, and then Mr. Campbell Cook struck on the very brilliant idea that we should fit out all the ships that cross the Atlantic to carry oil in their double bottoms. I assure you that it was a very difficult undertaking. There were immense technical difficulties to overcome ; there was immense opposition from various very powerful corporations. Although I believe in the East oil has been carried in double bottoms with light cargoes, you must remember the difficulties that were involved in fitting the somewhat intricate technical details into the ships, and, in addition, the opposition of every other Government Department. Every other Government Supply Department wanted to bring in the most they could, and they argued that every ton we brought in shut out a ton of something else. Therefore it was not an easy problem. If it had not been for the support of Mr. Walter Long, who is now, I am glad to say, First Lord of the Admiralty, who at that time was Colonial Secretary and had been appointed by the War Cabinet to the supreme control of all petroleum, and whose absolute unfailing support we always possessed, and also to the very able, cordial and generous assistance I received from Sir John Cadman, who is the

head of the Petroleum Executive, I do not know what would have happened. However, the double bottoms did really snatch us right out of the fire. I might mention that the first consignment of oil shipped in double bottoms was in July, 1917, and before the Armistice was signed, no less than one million tons of oil fuel had been carried in double bottoms across the Atlantic.

Sir Frederick Black, who had just returned from India, was appointed to represent our interests in the United States of America. Certainly a very considerable difference had been made, from our point of view, by America joining in the war, because we did feel, before America joined in and took her share in the fighting, that she was not doing all she could, although she was not willingly letting us down. When Sir Frederick Black was appointed to look after our interests on the other side, we all felt quite certain that before long we should get at all events what was absolutely vitally necessary to run the British Navy; and in not a very great many months after that, the situation considerably lightened, and before the Armistice had been concluded we had got what was, I should say, the very low but still the official minimum of three months' stock of petroleum, a small enough reserve, which some gentlemen with whom I was working, I am afraid, thought was pitched a little too high by me; but I can assure you it was just the other way about. I am sorry to have kept you so long, and I conclude by thanking you again very heartily on behalf of the guests for the most kind manner in which you have drunk our health. (Cheers.)

The Rt. Hon. Viscount Cowdray, P.C. :—

Mr. President, my lords and fellow-members of the Institution, I rise with a certain amount of diffidence to say two or three words only, but I feel that I cannot allow the claims of the Admiralty to go unchallenged. I am afraid that silent Service works in water-tight compartments, with the result that one Department hardly knows what the other does. I suggest that the great naval Service, known throughout the world for its fair play, and for giving to others recognition when it is their due, has for once failed in its traditions. We have heard a great deal about the pipe-line across Scotland, about the great protection it is going to be to England in protecting us from the Scots. (Laughter.) The initiator of the pipe-line, the man who suggested the pipe-line, has been entirely ignored. It might have been an Admiralty suggestion, as I gather from Sir Frederick Black, but I should like to place the facts before you. It originated in a suggestion made to the Admiralty by a member of my staff and by a son of mine. I thought it was only due to you to tell Sir Frederick Black and Sir Hugh Tothill that

this pipe-line was, as a fact, the outcome of a suggestion made to the Admiralty by Mr. John S. Smith, a member of the Institution who is in my employ, and by my son. (Cheers.) In this connection I should like to record a reminiscence of something that occurred about 8 or 10 years ago. I happened to be dining out one night, and I took in to dinner a very charming, attractive, but rather aggressive American lady. During the course of the dinner she was rather belittling England, and pointing to the great things that the Americans were doing. At that time the Americans were making four tunnels from New York to Long Island, and she said to me: "Just imagine, here's one of our railway Companies spending £20,000,000 of money, 100 million dollars, in the construction of these tunnels, and in providing a magnificent entrance into New York for the Pennsylvania Railway that no English Company would ever dream of doing, that no English engineer would ever think was within the range of possibility: what do you say to that?" I said: "Well, we happen to be making the tunnels!" (Laughter and cheers.) I simply rose to say that the pipe-line in Scotland was not at all events entirely originated at the Admiralty. (Cheers.)

Sir Frederick Black: May I say that when Lord Cowdray speaks of these watertight departments at the Admiralty being so distinct, he has forgotten that one little Department was over in America, and only in touch by cable and wireless with the Department on the other side, and the fact of where the suggestion originated was not mentioned in any of the cables I received from this side. Therefore, I naturally attributed the scheme to Admiralty initiative.